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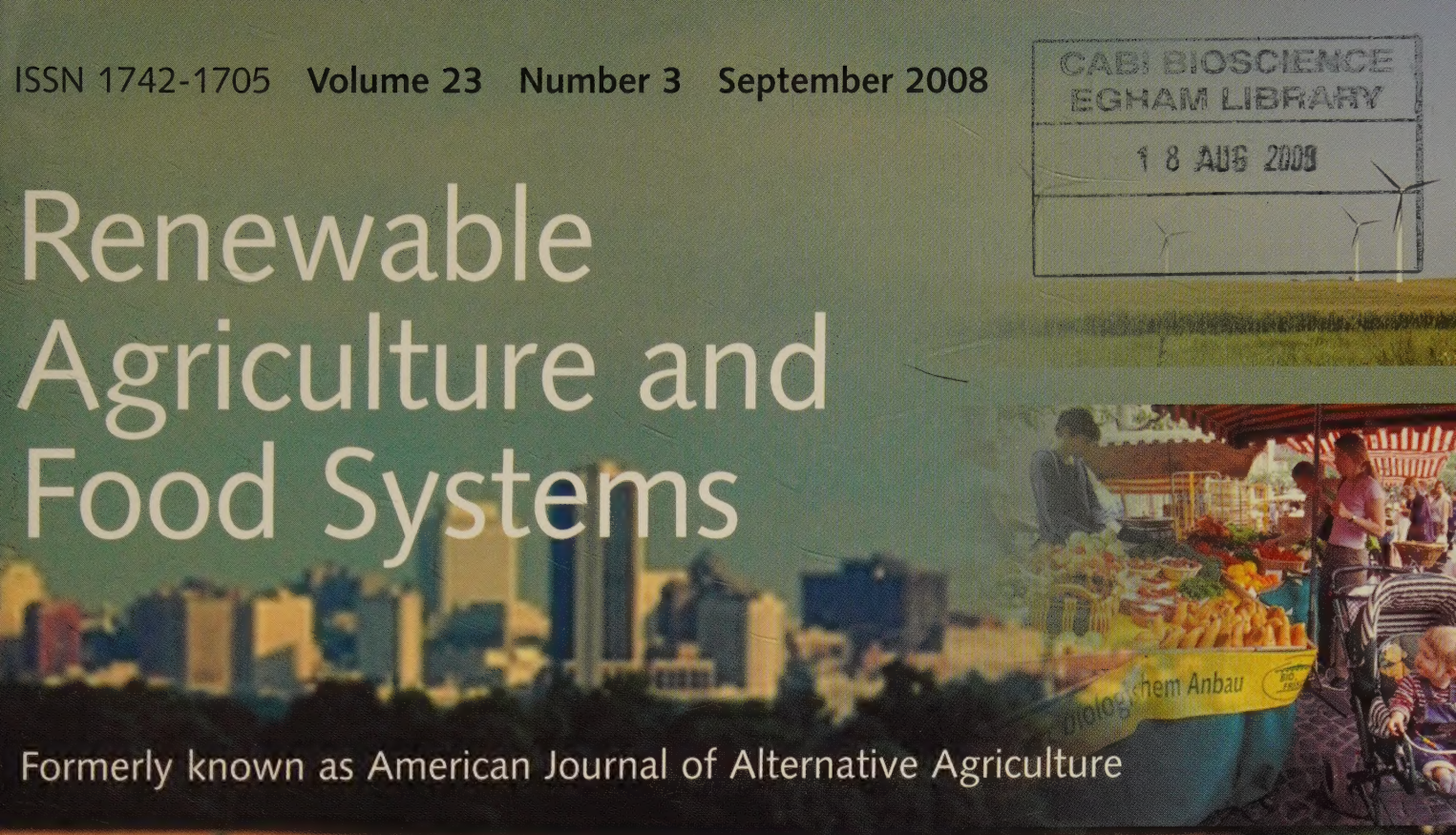

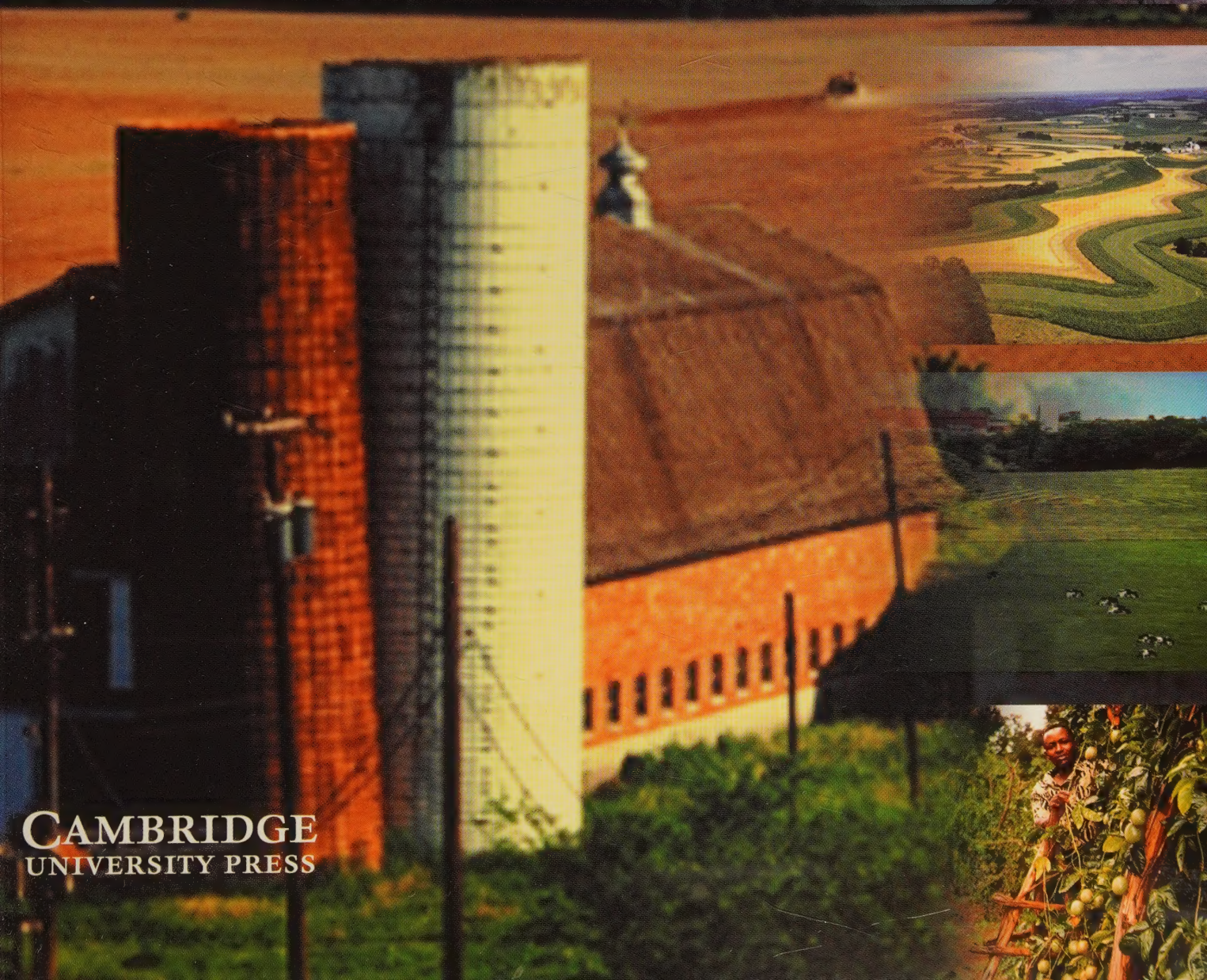

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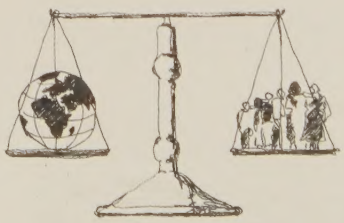

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# Assessing farmer interest in participatory plant breeding: Who wants to work with scientists?

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## Abstract

Participatory research, particularly participatory plant breeding (PPB), can increase the relevance of public-sector research to the agricultural community. PPB has mostly been used in developing countries with resource-poor farmers, but there is increasing interest among farmers in developed countries who are dissatisfied with the performance of available varieties. In 2006, scientists associated with the winter and spring wheat breeding programs in the Department of Crop and Soil Sciences and the Department of Community and Rural Sociology at Washington State University (WSU) conducted a survey of members of the Washington Association of Wheat Growers. Through analysis of the survey results, we sought to understand (1) whether or not farmers want to work with scientists in PPB programs and (2) the determinants of PPB interest. Results indicated that 52% of Washington wheat growers were interested in working with WSU scientists in a participatory breeding program. Interested farmers tended to be younger and college educated with fewer years of farming experience. Moreover, PPB interest appeared to be related positively to farm size, the number of wheat varieties planted, use of and interest in alternative production and marketing practices (e.g., seed saving, organic agriculture), and prior experience with WSU. Based on this analysis and ongoing discussions with farmers, we hope to develop a participatory wheat breeding program where farmers are able to choose their level of involvement with the breeding process based on their interest and needs. This new program will increase the relevance of WSU's wheat breeding programs to farmers in the state and could serve as a model for other public agricultural research programs seeking to increase farmer involvement and, thereby, democratize agricultural research.

**Key words:** democratization of science, participatory research, participatory plant breeding, wheat production

## Introduction

The traditional mission of US Land-Grant universities dictates that scientists conduct research of direct relevance to people and communities. To accomplish this task, it is important for the public to take an active role in setting research priorities, participating in actual research projects and providing feedback about the consequences of research outputs. Some scholars and activists argue that citizen involvement can contribute to the 'democratization' of university science and technology decision-making[1,2]. When citizens are involved in the research process, research results are more likely to be relevant, accepted and put into action. Examples of citizen involvement include consensus conferences, science shops (i.e., entities that conduct independent, participatory research in response to concerns expressed by civil society), participatory action research and community–based research[1]. Other scholars have focused specifically on the need for more democratic participation in the public agricultural research enterprise[3–7]. They argue that farmers, the primary beneficiaries of most research conducted in colleges of agriculture at Land-Grant universities, should be actively engaged in the research process. Participatory plant breeding (PPB), the focus of this paper, is one example of how scientists and farmers are attempting to democratize public agricultural research.

PPB uses both scientists' and farmers' knowledge to develop crop varieties suited to particular agro-ecological zones. In PPB projects, scientists and farmers work together to set breeding objectives, generate genetic variability, make selections, evaluate experimental varieties and generate and disseminate seeds. Agricultural scientists

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interested in these types of participatory research approaches certainly want farmers involved in their programs. However, less is known about why farmers, especially in more developed agricultural areas such as the United States and Europe, want to work with scientists in participatory research projects. What distinguishes those farmers who indeed want to work with university scientists? For example, are small-scale farmers, who are often the targeted beneficiaries of participatory breeding projects in developing countries, more interested than large-scale farmers? Are 'alternative' farmers more interested than 'conventional' farmers? Are farmers with pre-existing Land-Grant University ties more interested than farmers who have had little or no contact with public agricultural scientists and extension specialists? These and related questions form the basis of the analysis presented in this paper.

Specifically, we analyze data from a survey of Washington wheat growers to better understand (a) whether or not farmers want to work with scientists in participatory breeding programs and (b) the determinants of interest in PPB. We consider six sets of potential determinants of interest: farmer characteristics (e.g., gender, age, education), farm characteristics (e.g., farm size, wheat acreage, farm organization), production practices (e.g., number of wheat varieties planted, seed saving, interest in certified organic production), marketing strategies (e.g., niche marketing, marketing clubs), experience working with university researchers and extension specialists, and opinions about university research and extension. Most PPB programs in developed countries have been initiated at the request of relatively small-scale organic farmers involved in organizations with ties to research universities. However, other types of farmers might also be interested in PPB. We hope this study will help broaden our understanding of whether and why farmers in developed countries are interested in working with university scientists in PPB programs.

## From Formal to Participatory Plant Breeding

Formal plant breeding is conducted by professional scientists employed primarily by public agricultural research institutions or the private sector. These scientists set breeding goals, make crosses, test for desired traits, select superior lines and release new varieties without the organized participation of farmers. While most professional plant breeders make an effort to understand farmers' needs, they rarely include farmers in the day-to-day decision-making of formal breeding programs. Formal plant breeding rests on the assumptions that farmers are not capable of making crosses and keeping track of progeny lines[8] and professional plant breeders are better equipped to use complex selection systems to select superior varieties[9]. Plant breeders may also believe using farmers' management practices complicates experimental design and analysis[10]. Formal plant breeding became the norm in many countries because of increased scientific understanding of genetic principles, the industrialization of agriculture and investment in national agricultural research programs.

While it is true plant breeders have training in selection theory and experimental design, farmers also have valuable knowledge about environmental conditions and the characteristics that make a variety successful in their region. Many farmers already do their own research in testing and adapting new ideas and technologies[11]. Farmers in marginal agricultural environments often maintain and improve varieties developed over centuries of on-farm selection. Making use of both farmer and researcher knowledge can increase the relevance and efficiency of breeding programs. Therefore, over the past two decades, participatory approaches have gained popularity within formal international plant breeding programs.

PPB seeks to 'reverse the historical trend of separation between farmers and plant breeders, bringing them together in the process of developing new crop varieties or improving existing ones'[12]. PPB arose out of the realization that many farmers in marginal production areas were not benefiting from conventional plant breeding programs. While modern varieties developed by conventional breeders have been widely adopted, they are grown primarily in areas of high agricultural potential. These varieties were selected in such high-potential environments and are well adapted to these systems. As a result, the adoption of modern varieties has been very low in complex, diverse and risk-prone environments[13]. PPB emphasizes collaboration and knowledge sharing between farmers and scientists as essential for identifying and improving suitable varieties for these marginal environments[14]. Although PPB usually refers to farmer participation in selecting from diverse plant populations, farmer participation can take other forms including helping to set research priorities and breeding goals, engaging in on-farm field trials and providing feedback on released varieties. Different farmers may wish to participate in different stages of the process depending on their interests and time availability.

Because PPB was originally developed for farmers on marginal land in developing countries[15], some question if it is relevant to agricultural systems in favorable environments[16,17]. The farms associated with these systems tend to be large-scale, capital-intensive and oriented toward commodity markets. The use of high-yielding modern varieties is the norm, and little if any of the farm output is for the farmers' own consumption. The use of farm inputs such as fertilizers and pesticides makes growing conditions similar from farm-to-farm and region-to-region, so a few varieties may perform well over a wide spectrum of environmental conditions. However, restricting genetic diversity to only a few varieties increases the vulnerability of agricultural systems to disease or pest epidemics and environmental stress. A single production practice or crop variety will not be universally effective[18].

While formal plant breeding programs have produced very successful varieties for developed agricultural

systems, this does not mean these systems would not benefit from increased participation of farmers in the process of crop improvement. Highly productive areas have the potential for greater diversity in crop species and varietal diversity within species[17]. This diversity can include both specific adaptation to the biological and physical environment, and suitability for specific markets and end-uses[19]. Breeding crops adapted to specific farming systems and ecological zones is important for the sustainability of these systems and will require decentralized and participatory breeding programs to address the needs of a diverse landscape. Moreover, farmers have become increasingly interested in reducing the use of inputs (for both environmental and economic reasons) and finding alternatives to the conventional commodity system.

There are many examples of small-scale farmers in developing countries[13,20–24] and alternative agriculturalists in developed agricultural systems[25–27] engaging in PPB programs. A case study of participatory wheat breeding in southern France, for example, found PPB was primarily of interest to organic farmers and had become a political strategy for farmers' associations that felt conventional breeding programs were not able to meet the needs of more sustainable agricultural systems. PPB was seen as a means for farmers to regain independence in their choice of varieties[19]. Less represented in the literature are examples of PPB projects focused on larger-scale conventional farms in developed countries. Our study focuses on conventional Washington wheat growers, a majority of whom have been satisfied with university breeding programs. We hope this study will help broaden our understanding of why farmers in these systems might be interested in PPB approaches. Moreover, we offer the first analysis (to our knowledge) of some of the determinants of farmer interest in PPB in developed agricultural systems.

## Wheat Production and Breeding in Washington State

According to the 2002 Census of Agriculture, Washington has 3414 farms producing wheat for grain on 2,355,451 acres (953,217 ha)[28]. Most wheat growers are located in the eastern two-thirds of the state. The value of wheat production in the state was $456,316,000 in 2005[29]. In terms of production value, wheat is the fifth most important agricultural commodity in the state. Washington wheat growers produce 6.6% of all US wheat. Whitman County (the location of WSU) produces more wheat than any other county in the US[29].

There is a high degree of differentiation and strict quality standards for each market class of wheat. Common market classes in eastern Washington are hard red (used for bread and Asian noodles) and soft white (used for pastries, crackers and other baked goods). Hard white wheat (used for wholewheat bread and noodle products) is a newer market segment beginning to attract growers' interest. Based on roundtable discussions with wheat growers, it appears interest in alternative marketing strategies is driven by the expectation for a higher economic return from niche or specialty markets compared to the conventional commodity market.

Many farmers know environmental conditions influence quality. Moreover, they know matching varieties and market classes to particular environmental conditions can improve both quality and consistency. The lower rainfall zones (150–400 mm per year) of eastern Washington produce high quality bread wheat, while the higher rainfall zones (up to 600 mm per year) produce excellent pastry wheat. These geographic advantages are lost if multiple wheat varieties from multiple locations within the state are mixed in the commodity system. Thus, some farmers are interested in 'identity-preserved marketing' whereby specific varieties are grown for quality and sold at a premium.

Because of the wide range of environmental conditions in eastern Washington, scientists associated with the WSU winter wheat breeding program believe participatory methods could be appropriate for developing new varieties. While there are breeding nurseries and varietal evaluation trials throughout eastern Washington, the diversity of environments makes it very difficult for the program to develop varieties specifically for all farming systems and microclimates. Thus, in 2003, WSU scientists began working closely with a farmer in the dryland wheat–fallow cropping system. They have since expanded their program to include three other farmers. Genetically diverse populations of wheat have been developed using an evolutionary participatory approach, which combines natural selection and site-specific farmer selection[14].

In an effort to reach more interested farmers, scientists associated with WSU's winter and spring wheat breeding programs decided to conduct a mail survey of wheat growers in the state. The survey (discussed in more detail below) was designed to improve the relevance of the breeding program through a better understanding of farmer production practices, priorities and attitudes.

## Methods

A mail survey of Washington wheat growers was conducted from January through March 2006. The survey was designed and sponsored by the winter and spring wheat breeding programs in the Department of Crop and Soil Sciences and faculty in the Department of Community and Rural Sociology at WSU. The survey was conducted with the cooperation of the WSU's Social and Economic Sciences Research Center.

Survey questions were developed after eliciting farmer input. Questions dealt with many of the issues that surfaced during roundtable discussions with farmers in five eastern Washington counties. The survey's objective was to better understand how farmers make decisions about new technologies, production practices and marketing strategies. The survey included questions about experiences with

WSU representatives, opinions about WSU's wheat breeding programs, desirable traits for new wheat varieties, wheat marketing strategies, perceived farming challenges and factors contributing to successful wheat farming. Other questions addressed genetically-modified (GM) wheat, organic farming, the development of perennial wheat and interest in breeding wheat varieties in collaboration with WSU breeders. The hope was to use the survey's findings to improve the relevance of WSU's wheat breeding programs.

The sampling frame for the study was the Washington Association of Wheat Growers (WAWG) membership list. The WAWG list is representative of commercial farmers who grow wheat as their primary crop. Small-scale and certified organic growers may be underrepresented in WAWG because of preferences for grower associations that better serve their information and networking needs. Nonetheless, because scientists associated with the WSU wheat breeding program work closely with commercial wheat farmers in eastern Washington, the WAWG list was deemed an appropriate sampling frame for this particular study. Moreover, use of the WAWG list provided the opportunity to investigate PPB interest among a population of growers who are not typically the focus of PPB research.

With permission from the WAWG Board of Directors, questionnaires titled 'Wheat Production in Washington: Your Experiences with WSU and Input for Future Directions', cover letters, and business reply envelopes were mailed to all 1374 WAWG members on 14 February 2006. Survey procedures followed the Tailored Design Method[30]. Reminder postcards were sent out on 21 February 2006. Two weeks later (7 March 2006), second copies of the questionnaire were sent to non-respondents. Three hundred and seven (307) individuals were excluded because of ineligibility, bad addresses, and other reasons. The result was a corrected sample of 1067 growers. Of these, 553 wheat growers returned completed questionnaires. The completion rate for the survey was 51.8%, which is quite high for this type of farmer survey.

In this paper, our dependent variable is *interest in PPB*. It was measured by the following survey question: 'How interested are you in working directly with a WSU scientist in a participatory wheat breeding program within the next 1–3 years?' A box appeared next to the question with the following information: 'Participatory wheat breeding uses both breeder and farmer expertise to develop varieties particularly suited to a specific set of environmental challenges.' Answer categories included 'very interested,' 'somewhat interested' 'somewhat uninterested,' and 'very uninterested'. We created a dichotomous variable by grouping the first two categories (into 'interested') and the last two categories (into 'not interested'). Four hundred and ninety-three (493) respondents provided valid answers to the question. Results indicate that 258 growers (52.3% of respondents) are interested in working with a WSU scientist in a participatory wheat-breeding program, while 235 growers (47.7%) are not interested (see Fig. 1).

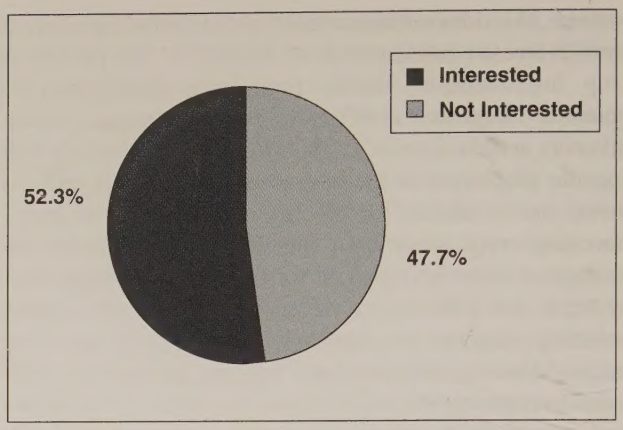


**Figure 1.** Interest in working with Washington State University (WSU) scientists in participatory wheat breeding programs, Washington wheat growers, 2006.

The primary objective of the analysis presented below is to explore the relationship between our dependent variable (interest in PPB) and six sets of independent variables. Our independent variable groups include farmer characteristics, farm characteristics, production variables, wheat marketing variables, variables measuring experience with WSU researchers and extension specialists and variables measuring opinions about WSU research and extension. All of the independent variables presented in the tables were measured by direct survey questions. The continuous variables (such as age, years in farming, total acres farmed, etc.) have been recoded as categorical variables for the purposes of analysis. We conducted Pearson chi-square tests to determine whether growers *interested* in PPB and growers *not interested* in PPB differ significantly in various characteristics. The Pearson chi-square test is designed to test for independence between two nominal variables. The null hypothesis is that the two variables are statistically independent. The test is based on a comparison between the observed and expected frequencies in the cells of a cross-classification table.

## Findings

Table 1 presents percentage distributions for farmers' interest in PPB by four farmer characteristics: gender, age, education and years in farming. There are statistically significant differences in PPB interest for three of the four demographic variables. Younger farmers, as well as individuals with less farming experience, are more interested in PPB. Note, however, that these are not mutually exclusive groups because of the high correlation ($r = 0.81$) between age and number of years in farming.

The data in Table 1 indicate a negative (and nearly linear) relationship between PPB interest and both age and number of years in farming. This could be due to a number of factors. Younger and newer farmers may be more willing to start a long-term project with the prospect of significant benefits down the road. For example, they may be looking

**Table 1.** Percentage distribution of interest in PPB by farmer characteristics, Washington wheat growers, 2006.

| Farmer characteristics | *N* | % of total sample | % Interested in PPB | Chi-square |
|---|---|---|---|---|
| Gender | | | | |
| Male | 494 | 96.3 | 53.5 | |
| Female | 19 | 3.7 | 25.0 | 3.803 |
| Age[1] | | | | |
| Under 45 | 58 | 11.4 | 70.4 | |
| 45–54 | 173 | 34.1 | 59.0 | |
| 55–64 | 148 | 29.1 | 54.5 | |
| 65 and over | 129 | 25.4 | 29.9 | 31.738*** |
| Education | | | | |
| High school degree or less | 50 | 9.8 | 28.6 | |
| Some college | 131 | 25.8 | 38.9 | |
| Vocational degree | 51 | 10.0 | 57.8 | |
| College degree | 206 | 40.6 | 64.7 | |
| Some postgraduate work | 30 | 5.9 | 59.3 | |
| Postgraduate degree | 40 | 7.9 | 43.2 | 31.621*** |
| Number of years in farming[2] | | | | |
| Less than 15 | 39 | 7.7 | 77.8 | |
| 15–29 | 179 | 35.4 | 60.7 | |
| 30–44 | 193 | 38.1 | 50.9 | |
| 45 or more | 95 | 18.8 | 30.1 | 30.513*** |

[1]The average age of survey respondents was 57.5 years.
[2]The average number of years in farming was 32.0 years.
*$P \leqslant 0.05$; **$P \leqslant 0.01$; ***$P \leqslant 0.001$ (Pearson chi-square test).

for alternatives to conventional commodity production out of concern for the long-term economic and environmental viability of their operations. Younger and newer farmers may also be experimenting with different production practices and varieties as they get to know the specific conditions on their farms. Older and more experienced farmers, in contrast, may already know the types of varieties and production methods that work well on their farms and, consequently, may not be as interested in making significant changes to their operations.

The data in Table 1 also suggest that interest in PPB varies significantly by farmers' level of education. Respondents with high school degrees (or less) are the least interested in PPB, while respondents with vocational degrees, college degrees and some postgraduate education exhibit the greatest PPB interest. One possible explanation for these findings is that more educated farmers are more aware of WSU research or plant breeding in general. Many farmers in Washington are WSU graduates, which could influence their interest in working with WSU scientists. Interestingly, only 43% of respondents with postgraduate degrees are interested in PPB.

Table 2 presents percentage distributions for farmers' interest in PPB by farm size, winter and spring wheat acreage, farm business organization, total farm receipts and percentage of household income from farming. Chi-square results indicate a statistically significant relationship between PPB interest and farm size, but not farm business organization or the percentage of household income from farming. The most intriguing finding is that farmers' interest in PPB increases with farm size, regardless of whether measured in terms of total acres farmed, wheat acres, or farm receipts. This finding does not support the common perception that smaller growers are the ones most interested in participatory research[25–27]. There are several possible explanations for our finding that larger-scale farmers seem to be more interested in PPB. First, farmers with more acreage may be more likely to have some marginal land, for which they want to work with scientists to develop special varieties. Secondly, large-scale farmers (compared to small-scale farmers) may have access to more resources and laborers, resulting in their ability to devote more time to participatory breeding projects. Thirdly, it is possible that some larger-scale farmers were able to expand their operations because of successful experimentation with new practices. These farmers may look favorably upon opportunities to experiment further.

Another interesting finding from Table 2 is the lack of a statistically significant relationship between PPB interest and the percentage of household income from farming. Farmers who rely on farm receipts for their entire income and those with off-farm income sources appear to be equally interested in participatory breeding programs. Off-farm income might provide a financial cushion to allow farmers to assume the risks of a participatory breeding program. However, farmers with off-farm jobs may face time constraints that could negatively affect their ability to participate in plant breeding activities. In contrast, farmers

**Table 2.** Percentage distribution of interest in PPB by farm characteristics, Washington wheat growers, 2006.

| Farm characteristics | *N* | % of total sample | % Interested in PPB | Chi-square |
|---|---|---|---|---|
| Total acres farmed[1] | | | | |
| 1–1000 acres | 77 | 15.0 | 29.0 | |
| 1001–2000 acres | 133 | 25.9 | 48.7 | |
| 2001–3000 acres | 115 | 22.4 | 53.8 | |
| 3001–4000 acres | 80 | 15.6 | 54.7 | |
| 4001–5000 acres | 36 | 7.0 | 73.3 | |
| 5001 acres or more | 73 | 14.2 | 63.8 | 24.777*** |
| Acres of winter wheat in 2005[2] | | | | |
| 0–500 acres | 139 | 27.2 | 37.2 | |
| 501–1000 acres | 143 | 28.0 | 56.4 | |
| 1001–1500 acres | 102 | 20.0 | 56.2 | |
| 1501 or more | 127 | 24.9 | 60.7 | 15.800*** |
| Acres of spring wheat in 2005[3] | | | | |
| None | 217 | 43.7 | 45.5 | |
| 1–250 acres | 123 | 24.7 | 59.1 | |
| 251–500 acres | 70 | 14.1 | 48.4 | |
| 501 or more | 87 | 17.5 | 65.8 | 11.894** |
| Farm business organization | | | | |
| Single family or individual operation | 147 | 29.1 | 43.8 | |
| Family partnership | 112 | 22.1 | 54.1 | |
| Family corporation | 221 | 43.7 | 58.2 | |
| Other | 26 | 5.1 | 47.8 | 6.829 |
| Total farm receipts in 2005 | | | | |
| Less than $25,000 | 22 | 4.6 | 36.8 | |
| $25,000–$49,999 | 19 | 4.0 | 29.4 | |
| $50,000–$99,999 | 37 | 7.7 | 37.5 | |
| $100,000–$249,999 | 172 | 35.9 | 50.0 | |
| $250,000–$499,999 | 146 | 30.5 | 59.8 | |
| $500,000 or more | 83 | 17.3 | 59.5 | 13.070* |
| % of household income from farming | | | | |
| 0–24% | 72 | 14.4 | 51.6 | |
| 25–49% | 67 | 13.4 | 56.4 | |
| 50–74% | 98 | 19.6 | 55.6 | |
| 75–100% | 264 | 52.7 | 50.8 | 0.956 |

[1]The average total acreage was 3145 acres.
[2]The average winter wheat acreage was 1183 acres.
[3]The average spring wheat acreage was 280 acres.
*$P \leqslant 0.05$; **$P \leqslant 0.01$; ***$P \leqslant 0.001$ (Pearson chi-square test).

who rely solely on farming for their household income might have the incentive and flexibility (especially in terms of labor time) to develop varieties for specific environmental conditions on their farms.

Table 3 presents percentage distributions for farmers' interest in PPB by various production variables. We find statistically significant chi-square results for all but two of the variables included in the table. Respondents who planted three or more public wheat varieties were more likely to be interested in PPB. Perhaps these growers are more aware of differences in variety performance across different sections of their farms. Growers who agree that 'specific wheat varieties should be grown only in appropriate geographic locations due to quality concerns' are more likely to exhibit PPB interest. This lends additional support to the hypothesis that farmers with PPB interest are more aware of the environmental effects on varietal performance and the need for wheat varieties adapted to specific agro-ecological zones.

The data in Table 3 also suggest farmers who are interested in alternative production methods are more inclined to want to breed new varieties in partnership with scientists. First, farmers who save seed from wheat and other crops are more likely than farmers who do not engage in seed saving to be interested in PPB. Farmers save seed for many reasons, including the desire to be self-sufficient or to avoid the cost of purchasing seed each year. Since farmers would have control of the varieties developed through PPB, it is not surprising that farmers who want to control their own seed supply seem to be very interested in

**Table 3.** Percentage distribution of interest in PPB by production variables, Washington wheat growers, 2006.

| Production variables | *N* | % of total sample | % Interested in PPB | Chi-square |
|---|---|---|---|---|
| Private wheat varieties planted in 2005 | | | | |
| None | 274 | 55.4 | 49.0 | |
| 1 | 132 | 26.7 | 60.0 | |
| 2 | 61 | 12.3 | 52.7 | |
| 3 or more | 28 | 5.7 | 72.0 | 7.610 |
| Public wheat varieties planted in 2005 | | | | |
| None | 27 | 5.5 | 54.5 | |
| 1 | 119 | 24.3 | 42.2 | |
| 2 | 173 | 35.3 | 50.0 | |
| 3 or more | 171 | 34.9 | 66.2 | 16.450*** |
| Typically plant wheat seed saved from own fields | | | | |
| No | 316 | 61.5 | 47.6 | |
| Yes | 198 | 38.5 | 62.1 | 9.352** |
| Typically save seed for other crops (besides wheat) | | | | |
| No | 404 | 80.3 | 49.7 | |
| Yes | 99 | 19.7 | 65.9 | 7.474** |
| Interest in transitioning to certified organic production | | | | |
| Not interested | 457 | 86.1 | 49.3 | |
| Interested | 74 | 13.9 | 75.8 | 16.011*** |
| Interest in planting GM wheat varieties | | | | |
| Not interested | 170 | 34.2 | 48.0 | |
| Interested | 327 | 65.8 | 53.8 | 1.359 |
| Agreement with statement: 'Specific wheat varieties should be grown only in appropriate geographic areas due to quality concerns' | | | | |
| Strongly disagree | 12 | 2.3 | 44.4 | |
| Somewhat disagree | 70 | 13.1 | 43.1 | |
| Somewhat agree | 308 | 57.8 | 50.4 | |
| Strongly agree | 143 | 26.8 | 66.4 | 12.998** |

*$P \leqslant 0.05$; **$P \leqslant 0.01$; ***$P \leqslant 0.001$ (Pearson chi-square test).

PPB. Secondly, there is a statistically significant relationship between PPB interest and interest in transitioning to certified organic production. This is not altogether surprising because the growers who originally worked with the WSU winter wheat breeding program were organic producers. These growers may be turning to organic production as a means to reduce their dependence on external inputs (including seeds) or to sell high-quality wheat in alternative markets. Moreover, some growers may be interested in PPB as a result of their perception that varieties developed on-farm would perform better than existing varieties in organic systems. In fact, this perception has motivated organic farmers in Europe and the US to initiate PPB activities.

The data in Table 3 also suggest interest in planting GM wheat varieties is not related to interest in participatory breeding. Wheat growers may consider both participatory breeding and the development of GM varieties as strategies for improving plant varieties. This interpretation contradicts findings from case studies of participatory breeding in the US and Europe where growers were interested in participatory breeding as a method of ensuring control over seed supplies and preventing GM 'contamination' of seed stocks[19,25–27].

Table 4 presents percentage distributions for farmers' interest in PPB by three wheat-marketing variables. Specifically, respondents were asked to indicate their level of interest in three wheat-marketing strategies: maintaining the current commodity system, niche marketing of high-value wheat varieties and establishing marketing clubs to pool varieties for sale to end users. We find no statistically significant difference in PPB interest for farmers with different levels of interest in maintaining the current commodity system. In fact, 65% of the respondents with *no* interest in maintaining the commodity system and nearly 64% of those with *extreme* interest in maintaining the system are interested in participating in breeding programs. It is likely farmers who are interested in keeping the current commodity system, but also interested in participating in breeding programs, are concerned with reducing input costs. These farmers may see the development of their own wheat varieties as a way of reducing costs through varietal adaptation to specific environmental conditions. For example, if a farmer chooses to conduct selection with

**Table 4.** Percentage distribution of interest in PPB by wheat marketing variables, Washington wheat growers, 2006.

| Wheat marketing variables | *N* | % of total sample | % Interested in PPB | Chi-square |
|---|---|---|---|---|
| Interest in 'maintaining current commodity system' | | | | |
| Not interested | 24 | 4.3 | 65.0 | |
| Slightly interested | 143 | 25.9 | 53.8 | |
| Somewhat interested | 269 | 48.6 | 49.8 | |
| Extremely interested | 84 | 15.2 | 63.5 | 5.397 |
| Interest in 'niche marketing of high-value wheat varieties or products' | | | | |
| Not interested | 22 | 4.0 | 35.0 | |
| Slightly interested | 120 | 21.7 | 43.9 | |
| Somewhat interested | 209 | 37.8 | 48.4 | |
| Extremely interested | 171 | 30.9 | 69.7 | 24.958*** |
| Interest in 'marketing club that pools specific varieties to sell directly to end users' | | | | |
| Not interested | 31 | 5.6 | 28.6 | |
| Slightly interested | 147 | 26.6 | 46.3 | |
| Somewhat interested | 235 | 42.5 | 52.2 | |
| Extremely interested | 113 | 20.4 | 74.5 | 28.050*** |

*$P \leqslant 0.05$; **$P \leqslant 0.01$; ***$P \leqslant 0.001$ (Pearson chi-square test).

reduced herbicides or pesticides, the variety developed will most likely have improved tolerance to weed pressure and resistance to diseases or insects. Thus, over time, selection for low-input systems can lower input costs for the same yield and quality goals.

The data in Table 4 also indicate a positive (and somewhat linear) relationship between PPB interest and interest in the two 'alternative' marketing strategies: niche marketing and marketing clubs. There are several reasons why growers interested in alternative marketing strategies might be more interested in PPB. Growers may want to develop a specialty product that could be niche-marketed. Moreover, they may be interested in improving grain quality for direct marketing to end-users who value nutritional value and food product quality over yield and protein content. They may also see PPB as a means to diversify and lower input costs.

Table 5 presents percentage distributions for farmers' interest in PPB by several variables measuring farmers' experiences with WSU researchers/extension specialists and their programs. We find statistically significant chi-square results for all six variables included in the table. Not surprisingly, respondents who reported having had the most contact with WSU researchers and extension specialists expressed the greatest interest in working with WSU scientists in participatory breeding programs. Similarly, respondents who had attended one or more WSU field days were more interested in PPB compared to respondents who had not attended any field days. PPB interest also appears to be related positively to the degree of importance attributed to WSU extension specialists, researchers and field days as sources of information for decisions about growing wheat.

The data in Table 5 also indicate PPB interest is greater among farmers familiar with the WSU effort to breed perennial wheat compared to farmers unfamiliar with this effort. The objective of the perennial wheat-breeding project is to develop wheat plants that produce grain for multiple years. Although perennial wheat is still in the experimental stages, preliminary results have been presented at many wheat grower meetings. It is likely growers with an interest in the latest activities of the WSU wheat breeding programs (i.e., growers who attend grower meetings and other gatherings focused on WSU research programs) tend to express greater interest in new participatory breeding efforts.

Table 6 presents percentage distributions for farmers' interest in PPB by several variables measuring farmers' opinions about WSU research and extension programs. PPB interest does not appear to be related to the perceived degree to which WSU researchers and extension specialists have been successful at serving the needs of wheat growers. However, there is a positive relationship between PPB interest and the degree to which growers perceived that 'WSU research not adequately focused on farmer needs' negatively affected their farm operations. In other words, growers who reported being 'highly affected' by a lack of relevant WSU research were the most likely to be interested in working with scientists to develop new wheat varieties. This finding supports one of the key goals of PPB: to reach farmers who have not benefited from formal plant breeding programs. However, because the survey question pertained to 'WSU research' (in general) rather than the development of wheat varieties (in particular), we must exercise caution in interpretation. Interestingly, we do not find statistically significant relationships between growers' PPB interest and

**Table 5.** Percentage distribution of interest in PPB by variables measuring experience with WSU, Washington wheat growers, 2006.

| Experience with WSU | *N* | % of total sample | % Interested in PPB | Chi-square |
|---|---|---|---|---|
| Contact with WSU researchers | | | | |
| Not at all | 212 | 40.5 | 37.2 | |
| Once a year or less | 175 | 33.4 | 53.8 | |
| More than once a year | 137 | 26.1 | 75.4 | 48.853*** |
| Contact with WSU extension specialists | | | | |
| Not at all | 147 | 27.3 | 33.6 | |
| Once a year or less | 167 | 31.0 | 53.0 | |
| More than once a year | 224 | 41.6 | 65.2 | 31.755*** |
| Importance attributed to WSU extension agents/scientists as source of information for decisions about growing wheat | | | | |
| Not important | 109 | 21.8 | 31.0 | |
| Slightly important | 215 | 43.0 | 45.4 | |
| Mostly important | 142 | 28.4 | 52.8 | |
| Extremely important | 34 | 6.8 | 70.0 | 20.251*** |
| WSU field days attended (2001–2005) | | | | |
| None | 149 | 28.7 | 34.4 | |
| 1–2 | 123 | 23.7 | 43.1 | |
| 3–4 | 112 | 21.5 | 62.6 | |
| 5 or more | 136 | 27.2 | 70.8 | 42.615*** |
| Importance attributed to WSU field days as source of information for decisions about growing wheat | | | | |
| Not important | 169 | 33.5 | 33.3 | |
| Slightly important | 200 | 39.6 | 42.1 | |
| Mostly important | 103 | 20.4 | 52.7 | |
| Extremely important | 33 | 6.5 | 65.4 | 18.067*** |
| Familiarity with WSU effort to breed perennial wheat | | | | |
| Not familiar | 252 | 52.8 | 44.9 | |
| Familiar | 282 | 47.2 | 60.3 | 11.613*** |

*$P \leqslant 0.05$; **$P \leqslant 0.01$; ***$P \leqslant 0.001$ (Pearson chi-square test).

their level of satisfaction with WSU's winter and spring wheat breeding programs. Growers who feel negatively affected by lack of attention by WSU researchers could certainly benefit from participation in research specifically tailored to meet their needs for certain varietal characteristics. These growers may also be interested in participating in priority setting or discussions about the overall goals of breeding and research programs.

## Summary and Conclusion

The objective of our study was to broaden our understanding of whether and why farmers in developed countries are interested in working with university scientists in participatory breeding programs. Based on our analysis of data from a survey of wheat growers in Washington, we found approximately 52% of growers were interested in participating in university breeding programs. This finding suggests that it is not just social scientists, activists and (some) scientists who want to democratize university science and technology decision-making. A majority of farmers—at least in Washington State—also want a more participatory public agricultural research system. They themselves want to be actively engaged in the research process.

Many factors appear to be associated with growers' desire to work with professional breeders. Younger, college educated farmers with fewer years of farming experience were more interested in PPB compared to farmers with more years of farming experience and either no advanced degree or a post-graduate degree. Our data also indicated PPB interest was related positively to farm size (whether measured in terms of total acres farmed, total wheat acres, or total farm receipts) and the number of wheat varieties planted. Growers' use of and interest in alternative production and marketing practices (e.g., seed saving, organic farming, niche marketing and marketing clubs) were also related significantly to interest in participatory breeding. We found statistically significant chi-square results for all of our measures of growers' prior experience

**Table 6.** Percentage distribution of interest in PPB by variables measuring attitudes about WSU, Washington wheat growers, 2006.

| Attitudes about WSU | *N* | % of total sample | % Interested in PPB | Chi-square |
|---|---|---|---|---|
| Perceived degree to which WSU researchers have been successful at serving the needs of wheat growers | | | | |
| Very unsuccessful | 27 | 6.2 | 56.0 | |
| Somewhat unsuccessful | 48 | 11.0 | 57.5 | |
| Somewhat successful | 227 | 51.9 | 55.6 | |
| Very successful | 135 | 30.9 | 62.1 | 1.401 |
| Perceived degree to which WSU extension specialists have been successful at serving the needs of wheat growers | | | | |
| Very unsuccessful | 14 | 3.2 | 61.5 | |
| Somewhat unsuccessful | 52 | 11.8 | 50.0 | |
| Somewhat successful | 227 | 51.6 | 55.8 | |
| Very successful | 147 | 33.4 | 59.7 | 1.493 |
| Level of satisfaction with WSU's winter wheat breeding program | | | | |
| Very dissatisfied | 23 | 4.2 | 61.9 | |
| Somewhat dissatisfied | 77 | 13.9 | 54.5 | |
| Somewhat satisfied | 276 | 49.9 | 52.4 | |
| Very satisfied | 145 | 26.2 | 54.1 | 0.772 |
| Level of satisfaction with WSU's spring wheat breeding program | | | | |
| Very dissatisfied | 15 | 2.7 | 53.8 | |
| Somewhat dissatisfied | 74 | 13.4 | 53.2 | |
| Somewhat satisfied | 277 | 50.1 | 51.6 | |
| Very satisfied | 144 | 26.0 | 58.2 | 1.553 |
| Perceived degree to which 'WSU research not adequately focused on farmer needs' negatively affected farm operation | | | | |
| Not affected | 95 | 18.2 | 46.0 | |
| Hardly affected | 183 | 35.1 | 47.9 | |
| Somewhat affected | 197 | 37.7 | 56.9 | |
| Highly affected | 47 | 9.0 | 73.8 | 11.820** |

*$P \leqslant 0.05$; **$P \leqslant 0.01$; ***$P \leqslant 0.001$ (Pearson chi-square test).

with WSU (e.g., contact with researchers and extension specialists, number of field days attended, familiarity with WSU's effort to breed perennial wheat). Finally, our data indicated growers who reported being 'highly affected' by inadequate attention from WSU researchers were the most likely to be interested in working with scientists to develop new wheat varieties.

Until we conduct further roundtable discussions and interviews with growers, we can only offer preliminary interpretations of our findings and generalizations about which farmers are most likely to be interested in PPB. It is essential to keep in mind that farmers are an extremely diverse group. Different farmers will have different reasons for wanting to work with university plant breeders. Moreover, most farmers will pursue multiple strategies to ensure the success of their operation. PPB is likely to be one project among many contributing to the farm operation. We believe PPB is sufficiently adaptable to allow farmers to use it to achieve multiple goals. We hope PPB in Washington State and elsewhere will help farmers gain greater control of the development of varieties to meet their specific needs and desires. Increased farmer involvement in plant breeding has the potential to contribute to the democratization of research and technology development at public agricultural research institutions.

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# 'I'm getting desperate': what we know about farmers' markets that fail

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## Abstract

This paper explores hidden problems amid the impressive expansion of farmers' markets in Oregon and throughout the United States. Although markets are growing in number, a surprisingly large number of them fail. A challenge for many markets is inadequate revenue to support market operations such as paying for the management personnel to perform functions necessary to grow and sustain markets. Smaller markets may enter a downward spiral in which they cannot attract additional customers because they do not have sufficient vendors but cannot attract additional vendors because they do not have sufficient customers. The analysis identifies five intertwined factors associated with markets that fail: small size, a high need for products, low administrative revenue, a volunteer or low paid manager and high manager turnover. The paper also examines the more general issue of why some markets struggle by exploring a correlation between new markets and inexperienced managers, and effort thresholds for volunteer managers. Recommendations to assist markets toward success include better planning, manager and board of director training and community financial support. The findings of this study have broad application.

**Key words:** farmers' markets, local food systems, farmers' market management, farmers' market failure, small farms, sustainable agriculture

> I have an urgent plea for help. [Our] farmers' market currently has no produce except berries, and has no farmers planning to bring produce until late July or (more likely) early August .... I know there must be some farmers out there with lettuce and other vegetables. I'm getting desperate. We have customers asking every week 'where are the vegetables?' and lots of folks in our community have the WIC and Senior coupons to spend at the market. It's very frustrating being in a farming community and not having any farmers at the market!
>
> (Farmers' market e-mail discussion list posting, 2002).

This appeal epitomizes a farmers' market in distress. Despite laudable efforts by its organizers, this market closed permanently a few months later.

The rapid expansion of farmers' markets in Oregon and throughout the United States obscures the little known fact that a disturbing number of them fail. Between 1994 and 2005, a period for which there are reliable inventories, the number of farmers' markets in Oregon increased from 18 to 68. Nationally, farmers' markets have increased at a similar pace numbering over 4385 as of 2006, an addition of over 2600 markets in 12 years[1]. These are both net changes. A closer examination of individual Oregon farmers' markets reveals that during that period many markets closed. This fragility of individual farmers' markets even during a period of rapid expansion is both a cause for concern and a motivation for this study.

The topic of farmers' market failure is rarely addressed in the literature. The research reported here provides an important first examination of the issue offering a clearer but still incomplete picture of market failure. Although the focus is on one area in the US, the findings have broad application. This paper describes the dynamics of farmers' market startups and closures. It focuses on two important resources—administrative revenue and management personnel—used by farmers' markets. Data for a sample of

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markets that failed are examined along with factors associated with market failure. Lastly, areas of risk and recommendations to enhance market success are offered.

Economists associated with the United State Department of Agriculture (USDA) periodically inventory, analyze and report on farmers' markets in the United States. Several such reports have been published during the period of growth of US farmers' markets from the 1990s to the present[2–5]. These reports documented a significant expansion in the number of farmers' markets nationwide. Although they largely focused on the growth of farmers' market numbers, the authors also recognized that there were other processes taking place. Burns and Johnson[3] noted, 'Not all farmers' markets are successful and only anecdotal information exists on why some have failed' (p. 12). Later, Payne[5] pointed out, 'While farmers' markets have shown that they are beneficial to farmers, customers and local communities, many areas of study remain. One of the most important areas that merits further study is why markets fail' (p. 9).

Farmers' markets link small farmers with consumers in a unique social gathering and serve a key role in local food systems. Local food systems integrate production, processing, distribution and consumption to enhance the economic, environmental and social health of communities[6]. A useful term for describing this still emerging form of food system is 'civic agriculture'[7]. Civic agriculture describes a system made up of economic and personal relationships within a community. The concept emphasizes economic development balanced against the social and environmental objectives of a community. Regarding farmers' markets, Lyson points out:

> As social institutions and social organizations, farmers' markets can be important components of civic agriculture. They embody what is unique and special about local communities and help to differentiate one community from another[7] (p. 93).

As important components of local food systems, farmers' markets are valuable venues for small farmers. For instance, a North Carolina study that examined the use of direct marketing channels by small organic farmers revealed over 40% of the farmers relied on farmers' markets for nearly their entire annual income[8]. A California study found smaller farms were more dependent on farm direct marketing and farmers' markets were the predominant channel used with 80% of the participants employing it and 54% employing it exclusively[9]. In addition, the researchers observed, 'a large percentage of small direct marketers believed that they really had no choice but to market directly to consumers if they wanted their farm to survive'[9] (p. 18).

Farmers' markets serve pivotal roles for small farmers and local food systems and the success of each is closely tied to the other. An understanding of how and why markets fail is an important step in improving the viability of farmers' markets and therefore, maintaining and expanding a marketing channel for small farms and enhancing local food systems.

## Methods

The data presented here are one segment of a larger research project that examined farmers' market viability in the northwest region of the US[10]. The data were collected between 2002 and 2005. Both quantitative and qualitative research methods were used including a survey questionnaire administered by telephone, interviews and focus groups.

The data collection employed a participatory approach that included built-in protocols for participants to offer guidance and review findings. A key feature was a project advisory committee consisting of three research participants. This group provided guidance and input throughout the project. This approach 'informed' the research process at crucial stages maintaining a grounding and problem-orientation to the research project. Approaching research in this manner includes the participants as intellectual partners and allows them to set the research agenda and contribute local knowledge[11]. The use of committees to guide research projects is noted by van de Fliert and Braun[12] as among many sound participatory approaches.

To obtain information from individual farmers' markets for a full season of operation, the survey questionnaire concentrated on the 53 farmers' markets operating in Oregon during 2002 that had operated during the 2001 season. Creation of the survey questionnaire was carried out during meetings with the project advisory committee. Fifty of the 53 eligible farmers' markets participated in the survey. The 94% response rate strengthens the validity of a research study drawn from a numerically small population.

Following a preliminary analysis of the quantitative and qualitative data, six focus groups of farmers' market managers were organized and conducted on a regional basis during 2004. A total of 29 managers participated representing 33 farmers' markets. The focus groups were two-way conduits for information exchange between researchers and practitioners and added important data to the market failure segment of the project.

Directories of Oregon farmers' markets for 1998–2005[13–20] were used as an important secondary data source. The directories are published by the Oregon Farmers' Market Association (OFMA) and the Oregon Department of Agriculture (ODA) and have been produced annually since 1998. The OFMA/ODA directories list the markets operating for each year of the publication, their location, contact information and other information. These directories were used to identify the year markets began and ceased operating and to track manager turnover. Survey and interview data enhanced the accuracy of the directories since markets did not always appear in the directories the specific year they began operating.

A key aspect of this paper is an examination of a small sample of farmers' markets that closed. Nine markets that

**Table 1.** Growth in number of Oregon markets by year and markets that opened or did not re-open.

| Markets | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | Total |
|---|---|---|---|---|---|---|---|---|---|
| 1. New markets | – | 11 | 5 | 16 | 9 | 6 | 4 | 11 | 62 |
| 2. Markets not reopening[1] | – | 6 | 2 | 4 | 6 | 5 | 5[2] | 4 | 32 |
| 3. Total number of markets | 38 | 43 | 46 | 58 | 61 | 62 | 61 | 68 | – |

[1] Exact date of closure is unknown (during a season, after a season, or just prior to the next season).
[2] Text refers to nine closed markets in 2003–2004. The tenth market shown here had just opened in 2002 and was ineligible for participation in the survey.

were operating at the time of the 2002 survey of market managers closed sometime after the survey was conducted and prior to 2005. The 2002 survey of market managers includes data on seven of these nine farmers' markets that closed (two markets did not participate in the survey). The OFMA/ODA farmers' market directories provide limited but important information on all nine of the closed markets. Interviews with farmers' market managers and three managers of closed markets enhanced the survey and the secondary data.

Quantitative data from the survey questionnaire were organized and analyzed using Statistical Package for the Social Sciences (SPSS) version 11.5. Statistical analysis was conducted with consultative support from the Survey Research Center at Oregon State University.

## Farmers' Market Dynamics

Brown[21] documented the growth and decline in numbers of farmers' markets in the US during the 20th century identifying the 1990s as the beginning of a period of growth. This period of growth continues and Oregon market numbers are consistent with this national trend. Here, a more complete picture of Oregon farmers' markets numbers for this period is provided. Row 3 of Table 1 presents the total number of farmers' markets in Oregon for the years 1998–2005 based on the OFMA/ODA directories. It shows a relatively steady increase in the number of markets from 38 in 1998 to 68 in 2005. This type of information is commonly presented by researchers for this period of growth in the number of farmers' markets. For instance, Thilmany and Watson[22] used USDA data to document that between 1994 and 2002 the growth of western states farmers markets was 168% outpacing the national increase of 79%.

Rows 1 and 2 of Table 1 present the number of new markets that opened each year and the number of markets that had operated the previous year that did not reopen. For example, between the end of the 1998 season and the beginning of the 1999 season, 11 new markets opened and 6 markets that had previously operated did not reopen. Over the entire period from 1998 to 2005, 62 new markets opened and 32 closed. This is a more complex picture than is presented by just examining net growth. Remember, this relatively high rate of failure of markets occurred during a period of overall growth in the number of farmers' markets—a time when the farmers' market sector was portrayed as booming.

## Market Resources Influence Success and Failure

Organizers of farmers' markets make many highly individualized decisions that may contribute to the ultimate success or failure of their markets. However, all markets must obtain and use revenue and personnel resources to provide an environment for sound decisions and long-term sustainability. This is particularly crucial for the overwhelming majority of markets that depend on vendor fees for operation. Markets vary greatly in both revenue and personnel resources. Local supplies of customers and products play a role in what revenue may be generated by a farmers' market. Market revenues are often used to pay for personnel to manage market operations. When these tasks are carried out effectively they sustain the market by continuing the cycle of attracting customers and farmers.

### *Farmers' market size categories*

Four market size categories were developed as a step in analyzing the relationship of market scale to revenue, personnel employed and market failure. The 2002 farmers' market survey showed that markets ranged in size from 5 to 90 vendors. Table 2 presents the size categories *Micro*, *Small*, *Medium*, and *Large*, along with the number of vendors associated with each category, the number and percentage of markets in each size category and a footnote describing how the categories were created. The categories include all types of vendors participating in the market (farmers and craft vendors) because all vendors have an impact on market management (only 26% of Oregon farmers' markets do not allow craft vendors; other markets enforce a ratio of craft vendors to farmers to maintain a significant farmer presence or allow craft vendors without restrictions). These size categories are intended to be guidelines and the boundaries between categories should be seen as transitions rather than as hard divisions.

### *Revenue resources*

The value of revenue generated, in most instances, shapes the type and sophistication of the management organization of a farmers' market. Nearly all markets surveyed (92%)

**Table 2.** Size categories of Oregon farmers' markets (2002)[1].

| Category | Number of markets | Percent of markets |
|---|---|---|
| Micro (5–8 vendors) | 8 | 16 |
| Small (9–30 vendors) | 20 | 40 |
| Medium (31–55 vendors) | 12 | 24 |
| Large (56–90 vendors) | 10 | 20 |
| Total | 50 | 100 |

[1] The farmers' market categories integrate both quantitative and qualitative data. Categories formulated from the frequency distribution for market size and research participant input were examined statistically using analysis of variance (ANOVA) and Tukey's (HSD) test for honestly significant difference. Tukey's HSD revealed that the categories were significantly different for small, medium, and large markets ($P < 0.05$). It was not significantly different between micro and small markets ($P > 0.05$), however. Notwithstanding, there are sufficient qualitative differences between micro and small markets in terms of type of site, management structures and other factors that the category is useful. The market size categories were reviewed and validated during manager focus group sessions.

collect stall fees from vendors. These fees are the primary source of revenue for markets. Other sources of revenue for some markets include annual membership fees, promotional items, fundraising events, sponsorships, donations and grants.

## Haves and have nots

When USDA researchers inventoried farmers' markets during the mid-1990s, 84% of markets were described as 'self-sustaining' but that term was not defined[16]. A later USDA study indicated that a similar number (81%) were 'self supporting', which is defined as 'market income sufficient to pay for all costs associated with operating the market'[5] (p. 4). The more detailed data presented here call into question whether such a high percentage of Oregon markets can truly be called 'self-sustaining' or 'self supporting'. Many Oregon farmers' markets struggle to survive within the confines of a very limited budget for operating a farmers' market.

For the 50 farmers' markets that participated in the 2002 survey, the sum of all sources of revenue received by market administrators (stall fees, sponsorships, etc.) totaled nearly $1 million (US) for the 2001 season (the total based on manager survey responses is $991,969; some markets estimated their gross revenue so this figure should also be considered to be an estimate).

For clarity, this sum is *administrative revenue*, the financial resources used for operating the market. It is not vendor sales, which would be substantially higher. This $1 million figure is unevenly distributed among markets with most markets operating on very limited revenues.

Examining the markets on an individual basis offers a clear picture of the uneven distribution of administrative revenue. The annual administrative revenue for individual markets ranged from $0 to 111,000 (Table 3). Six markets (12%) generated less than $1000. In contrast, seven markets (14%) each generated more than $50,000 with one collecting more than $100,000. As a group these seven markets accounted for nearly half ($482,641) of the administrative revenue generated by all 50 farmers' markets. It is not surprising all seven were in the large market size category.

**Table 3.** Administrative revenue for individual Oregon markets (2002).

| Administrative revenue | Number of markets | Percent of markets |
|---|---|---|
| $0–999 | 6 | 12 |
| $1000–4999 | 12 | 24 |
| $5000–9999 | 9 | 18 |
| $10,000–19,999 | 8 | 16 |
| $20,000–49,9999 | 8 | 16 |
| $50,000–99,999 | 6 | 12 |
| $100,000 or more | 1 | 2 |
| Total | 50 | 100 |

Larger markets generate more revenue than smaller markets for two reasons: they have more vendors paying stall fees than small markets and they also charge higher stall fees ($r(50) = 0.502$, $P < 0.01$). To illustrate this, Table 4 shows that 88% of markets in the micro market size category and 65% of markets in the small market size category charge $0–12 per stall. Conversely, 80% of markets in the large market size category and 75% of markets in the medium market size category charge $13–35 per stall. Thus smaller markets face two challenges to generating market administrative revenue: fewer vendors from whom to collect fees and lower stall fees.

It is important to recognize that many farmers' market organizers do not seek to maximize market administration revenue. Most markets also focus on providing service to their customers, a venue for vendors to earn income and improved nutrition, food security and social enhancement of their communities. That said, the level of administrative revenue influences the ability of the market to access important resources. The major enhancement that can be provided by adequate administrative revenue is paid personnel to handle overall market operations.

## Management and personnel resources

All farmers' markets must handle both simple and highly complex tasks in order to operate during the market season and to maintain their management operations during the off-season. All Oregon farmers' markets have someone who functions in the role of coordinator or manager. Whether a manager is paid, as well as the level of pay are linked to how much administrative revenue a market generates.

**Table 4.** Larger Oregon markets charge higher stall fees (2002).

| Market size category | Category of fees[1] | | | | Total[2] |
|---|---|---|---|---|---|
| | $0–8 | $9–12 | $13–20 | $21–35 | |
| Micro (5–8) | 50% (4) | 38% (3) | 13% (1) | 0% (0) | 100% (8) |
| Small (9–30) | 35% (7) | 30% (6) | 25% (5) | 10% (2) | 100% (20) |
| Medium (31–55) | 8% (1) | 17% (2) | 42% (5) | 33% (4) | 100% (12) |
| Large (56–90) | 0% (0) | 20% (2) | 50% (5) | 30% (3) | 100% (10) |
| Total markets | 12 | 13 | 16 | 9 | 50 |

[1] Fee categories are arranged to approximate quartiles.
[2] Percentages are rounded to nearest whole number.

**Table 5.** Administrative revenue and salary of Oregon managers (2002)[1].

| Market administrative revenue | Salary range of managers | Number of managers[1] |
|---|---|---|
| Less than $5000 | $650–2600 + 11 volunteer mangers | 14 |
| $5000–9999 | $1000–7800 + 3 volunteer managers | 5 |
| $10,000–19,999 | $2700–12,000 | 5 |
| $20,000–49,999 | $10,000–20,000 | 3 |
| $50,000–74,999 | $9,000–28,000 | 4 |
| $75,000 or more | $23,000–35,000 | 3 |

[1] These figures are for farmers' market organizations and include organizations that manage multiple markets. There are a total of 40 individuals managing 50 farmer's markets.
Six managers are compensated by government or civic entities and are not included here.

Table 5 shows categories of administrative revenue for farmers' markets with corresponding salary ranges for managers. It illustrates two points: that volunteer managers are associated with markets that generate lower revenues and, more broadly, the manager's salary level is correlated with the administrative revenue a market generates. Markets with higher or lower administrative revenue compensate managers at higher or lower levels.

Payne[5] conducted a national study of US farmers' markets that provides additional information on the link between revenue and use of volunteer or paid managers. Using total revenue to vendors from sales, he observed that only 11% of markets with $10,000 or less in total sales had paid managers. In contrast, 75% of markets with vendor sales above $500,000 had paid managers.

The term 'paid manager' is relative. The range of manager salaries in 2002 was $650–35,000. Four managers made less than $1500, placing them close to volunteer status. Four managers making $20,000–35,000 approach what might have been considered a living wage at that time. To some degree, the compensation reflects the number of hours a manager works, as smaller, less management-intensive markets tend to require less effort. There are exceptions to this. Of concern to this analysis are situations in which a high level of effort is required to manage a market (such as when it is starting up or navigating through a crisis) but the market administrative revenue is insufficient to pay an adequate salary.

In sum, administrative revenue and management personnel are part of the foundation of most markets. Since the amount of market administrative revenue and the personnel resources it can provide are closely tied to the size of farmers' markets, smaller markets are at an immediate disadvantage. Smaller markets may find themselves in a downward spiral that starts with low vendor numbers resulting in low administrative revenue. The lack of revenue affects whether and how much the market can pay a manager. This, in turn, affects how much time and effort can be expended managing the market a task which includes recruiting vendors and customers.

## Some General Areas of Concern Related to Market Failure

Analysis of the aggregate data revealed several general areas of concern related to market failure. These areas of concern are the short life span of markets that close, a lack of market management experience of managers associated with newer markets, a threshold for the maximum number of hours worked by volunteer managers, and the high turnover rate of market managers.

### *Life span of markets that close*

Of the 32 markets that closed between 1998 and 2005, the overwhelming majority had short life spans (Table 6). Fifteen of the 32 markets (nearly 47%) closed following their first season. Moreover, 30 of the 32 markets (94%) that closed were less than four years old.

Although there is a high failure rate for younger markets, the rest of the story is the drop in the rate of failure after four years. Only two of the 32 markets that failed were older markets (11 and 22 years respectively). While this indicates that market failure is not an issue exclusive to younger markets, the rate of failure for older markets is remarkably lower.

**Table 6.** Life span of Oregon markets that closed 1998–2005.

| Number of years operating[1] | Number of markets | Percent of markets that closed |
|---|---|---|
| 1 | 15 | 46.8 |
| 2 | 5 | 15.6 |
| 3 | 4 | 12.5 |
| 4 | 6 | 18.8 |
| More than 4 years[2] | 2 | 6.2 |
| Total | 32 | 100 |

[1] For six markets, the exact number of years of operation was unknown. They are listed here as operating the number of years known. Four are recorded as 1 year, one is recorded as 3 years, and one is recorded as 4 years.
[2] These markets operated for 11 and 22 years.

## Years of manager experience and age of market

The 2002 survey of market managers indicated that the number of years of experience of market managers ranged from 1 to 20 years. Thirty-seven percent of market managers had only one year of experience and nearly half (47%) had two or fewer years of experience. While this may reflect the growth in numbers of markets in recent years, it is also a cause for trepidation. Although a farmers' market could suffer under an experienced but ineffective manager, a study by Oberholtzer and Grow[23] expressed concern with the correlation between experience levels of the market managers and years of operation for the market: 'Thus, in many cases, younger markets—those that could benefit a great deal from market manager experience—lack this amenity for farmers' (p. 24).

The 2002 survey data also reveal a correlation between manager experience and age of markets for Oregon. Newer markets have less experienced managers and older markets have more experienced managers ($r\,(50) = 0.387$, $P < 0.01$). Fifteen of the 16 markets that were 3 or fewer years old were managed by managers with 3 or fewer years of experience. The ten managers who had six or more years of experience were associated with markets that had been operating six or more years. Seven of the 10 managers with six or more years of experience were associated with markets that had been operating more than 10 years.

## Effort thresholds for volunteer managers

The 2002 survey of farmers' market managers showed 28% of markets use volunteer managers and 72% of markets employ paid managers. There is a clear relationship between the size of markets and the status of the manager. Volunteer managers are associated with smaller markets and paid managers are associated with larger markets ($t\,(48) = -4.917$, $P < 0.0001$). Table 7 shows the size categories of markets and the number and percentage that are managed by volunteer or paid managers. It is very significant that there are no medium or large markets managed by volunteers.

One implication is that volunteers reach a limit in the level of effort they are able or willing to provide. This issue was examined by analyzing effort for the volunteer managers in terms of number of hours worked. Volunteer managers average 6.8 hours per week during the market season, ranging from 1 to 15 hours per week (Table 8). Ten of the volunteer managers (77%) work 10 or fewer hours per week during the season. Off-season effort for volunteer managers averages 3.2 hours per week, ranging from 0 to 8 hours per week. Nine of the volunteer managers (69%) work three or fewer hours per week during the off-season.

The volunteers managed markets that ranged in size from 5 to 29 vendors with an average size of 14 vendors. Although five volunteer managers (36%) managed markets of 20 vendors or more, nine volunteer managers (64%) managed markets of 16 or fewer vendors. All of these markets fall into the micro and small categories.

There are no extensive data documenting what happens as a market grows beyond what a volunteer can manage relative to the market size and number of hours worked, so it is unclear whether they become overwhelmed or the quality of work declines. These data simply illustrate current practices. Based on these observations, it appears the threshold for volunteer managers is with markets that are approaching the mid-teens in numbers of vendors and when the manager's workload exceeds seven hours per week during the market season.

## Market manager turnover

Farmers' markets also experience high rates of manager turnover. Using data from the OFMA/ODA directories, the number of farmers' markets operating under a new manager is listed in Table 9 by year for the period 1999–2005. These figures represent the number of existing markets that began a season with a change in manager from the previous season and do not include new managers of new markets. For each year, a significant number of existing markets, ranging from 11 to 19, changed managers. The total for the

**Table 7.** Manager compensation and Oregon market size (2002).

| Managed by volunteer or paid manager | Micro (5–8) | Small (9–30) | Medium (31–55) | Large (56–90) | Total |
|---|---|---|---|---|---|
| Volunteer | 5 (55%) | 9 (47%) | 0 (0%) | 0 (0%) | 14 |
| Paid | 3 (45%) | 11 (53%) | 12 (100%) | 10 (100%) | 36 |
| Total | 8 (100%) | 20 (100%) | 12 (100%) | 10 (100%) | 50 |

**Table 8.** Hours worked by Oregon volunteer managers during and off-season (2002).

| Administrative revenue | Minimum/ maximum | Mean | $n^1$ |
|---|---|---|---|
| Hours worked during season | 1–15[1] | 6.8[2] | 13 |
| Hours worked during off-season | 0–8 | 3.2 | 13 |
| Number of vendors | 5–29 | 14 | 14 |

[1] Data for hours worked are available for 13 of the 14 volunteer managers. Data for market size are available for all 14 markets.
[2] One outlier of 30 h has been dropped from this analysis.

eight seasons is 101 manager changes for a weighted annual average 30% turnover rate in managers of existing markets.

Manager turnover is not necessarily negative. A change may improve a market or reflect a better opportunity for a manager. But, clearly, the high rate of turnover documented here cannot be all positive. Even under the best of conditions, a change in manager produces some stress for a market organization. The experiential literature from the non-profit sector notes that during gaps in leadership, 'Board members who are volunteers serving during their 'free' time, aren't prepared to manage critical challenges .... Inattention to day-to-day management or poor decision-making during the interim can wreak organizational havoc. The board will find itself pulled into serving as surrogate staff without adequate time or training, leaving its more important board duties under-attended' (p. 11)[24].

## Some Insights into Markets that Fail

This section presents data on a small sample of markets that failed and identifies five interrelated factors associated with failure. Then, managers of markets that failed offer their perspectives, revealing a greater level of complexity to the process of failure.

### *Five factors associated with farmers' market that fail*

The analysis so far has explored market failure on an aggregate basis. Here, the focus is specifically on the nine markets that were operating at the time of the 2002 survey of market managers but closed sometime after the survey was conducted and prior to 2005. This is a small sample of markets but the analysis sheds some light on the phenomenon of market closures.

As a group, eight of the nine markets that closed were operated as local not-for-profit and non-government community organizations. The ninth market was sponsored by a business that provided space for vendors but did not collect fees and provided only a basic level of management. Two of the community-based markets were associated with market organizations that managed more than one market. In these instances the markets closed but the market organizations continued operating and managing other markets.

**Factor 1: Small size.** Five of the markets that closed were in the micro size category and four markets were in the small size category. Survey data indicate the number of vendors for total market size (including craft vendors) ranged from 5 to 20 and the number of farmer vendors (source of food products) was 4–13. Because the survey was conducted during 2002 (based on vendor numbers from the 2001 season) and the markets closed sometime between that year and 2005, the actual number of vendors participating during the final season of the market is not known. As is discussed below, one aspect of a market's decline is a loss of vendors. Thus, some of these markets may have been even smaller just prior to closing.

**Factor 2: Need for products (lack of farmer vendors).** One question in the 2002 manager survey asked managers whether their markets would be improved by offering more of any of nine product categories commonly sold at farmers' markets. Table 10 presents the nine product categories with the percent of closed and operating farmers' markets answering YES. These affirmative responses indicate a shortage of products or a lack of diversity in the markets' offerings. All of the markets that subsequently closed indicated a need for more fruits and vegetables, products considered basic to farmers' markets. More than half of these markets indicated that the addition of eight of the nine product categories would improve the market. In all instances, the markets that closed expressed a higher percentage of need for products than the markets that did not close. This situation is directly connected to the small size of the markets in terms of the number of vendors noted in factor 1.

**Factor 3: Administrative revenue 'have-nots'.** The markets that closed were among the administrative revenue 'have-nots.' Five of the seven markets that participated in the survey collected less than $3400 per year in administrative revenue. The range in administrative revenue without temporary grants was $0–8000. With grants

**Table 9.** Number of existing Oregon markets operating under a new manager.

| Existing markets | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | Totals |
|---|---|---|---|---|---|---|---|---|
| New manager | 14 | 11 | 13 | 17 | 15 | 19 | 12 | 101 manager changes |
| Returning manager | 18 | 30 | 29 | 35 | 41 | 38 | 45 | – |
| Percent manager turnover[1] | 44% | 27% | 31% | 33% | 27% | 33% | 21% | Average 30% |

[1] Rounded to whole numbers.

**Table 10.** Percent of Oregon markets (closed and operating) responding that more of designated products would improve market (2002)[1].

| Market would be improved by offering more | Percent of closed markets ($n = 7$) | Percent of operating markets ($n = 43$) |
|---|---|---|
| Fruit | 100 | 56 |
| Vegetables | 100 | 54 |
| Fish | 100 | 72 |
| Meat | 100 | 67 |
| Value-added products | 100 | 61 |
| Cheese | 86 | 81 |
| Bakery products | 86 | 54 |
| Cut flowers | 57 | 35 |
| Nursery products | 43 | 26 |

[1] The 2002 survey of market managers includes data on seven of nine farmers' markets that were operating at the time of the survey but closed sometime after the survey was conducted.

included, one market's total administrative revenue was $20,000. This situation was temporary, and the market was forced to close when the grant ran out and the market was not sustainable based on vendor fees alone.

**Factor 4: Manager was volunteer or paid a low salary.** As noted previously, for the majority of markets there is a connection between the amount of money the market collects as administrative revenue and the amount spent on personnel to support the market. Given the situation described as factor 3, it follows that the markets that closed are often those that depend on volunteer managers or paid the manager a low salary.

Four of the seven managers were volunteers or were paid low wages. Of these four managers, two were volunteers and two were paid between $1040 and 2000 per year. One manager associated with a market organization that managed three markets was paid $20,000. One manager was compensated by the private business that sponsored the market. One manager was paid $12,000 per year through grant funds. Again, this market was not self-sustaining when grant funds were no longer available.

**Factor 5: High manager turnover.** As indicated, there is a high turnover rate among market managers in general (ranging annually from 21 to 44% with a weighted average of 30%). Even higher rates of manager turnover are associated with markets that close. Table 11 indicates the number of markets with new or returning managers between 2001 and 2005. All nine markets were operating in 2001 and all had closed by 2005. The percent manager turnover for each year ranges from 11 to 80% for a weighted annual average of 46%, overall considerably higher rates than the rate for all markets. The nine markets experienced 12 manager changes during the 5-year period, in fact five of the nine markets changed managers the majority of the years they operated. Significantly, seven of the nine markets began their final season with a new manager.

## *Manager perspectives on markets that fail*

Interviews with managers of markets that failed and other managers provide qualitative information that helps flesh out the quantitative data presented in this paper and by other researchers. The manager accounts note challenges achieving a positive balance between vendors and customers, integrating into communities and gaining community support, and problems within the market organization. They indicate a complexity of issues that swirl within markets and between markets and communities. These issues are rich areas for further inquiry.

Farmers' markets must manage a complex relationship between supply (vendors) and demand (customers). This relationship is different for farmers' markets than for most retail outlets. A viable farmers' market must have enough farmer vendors to attract customers and it must have enough customers to be attractive to farmer vendors. If the market is out of balance it may enter a downward spiral. Burns and Johnson[3] describe this situation:

> Farmers' markets, unlike retail stores, operate both on the supply side, with the farmers, and on the demand side, with the consumers. However, the overall retail marketing dynamic is operative. Consumers wish to have certain preconceptions met when selecting a retail site. If they are not met, the consumers will stop coming. Farmers will go to markets where they are guaranteed selling space and have exposure to enough customers to allow them to sell the majority of their product in an allotted time. When farmer ... and customer expectations are not met, both farmers and customers will look for alternative markets (p. 12).

All market managers are concerned with managing vendor and customer expectations to maintain a healthy balance. But many smaller markets seem to be particularly

**Table 11.** Manager turnover among failed Oregon markets 2001–2005.

| Existing markets | 2001 | 2002 | 2003 | 2004 | 2005 | Totals |
|---|---|---|---|---|---|---|
| New manager | 1 | 5 | 4 | 2 | 0 | 12 |
| Returning manager | 8 | 4 | 1 | 1 | 0 | 14 |
| Total markets | 9 | 9 | 5 | 3 | 0 | |
| Percent manager turnover[1] | 11% | 55% | 80% | 67% | – | |

[1] Rounded to whole numbers.

challenged by a general shortage of farm vendors, especially 'anchor vendors,' those farmers who can provide adequate quantities of a diverse array of products for an entire season. One manager commented on the issue of not having enough farmers and customers at her market:

> Farmer shortage is definitely our most critical issue. And when we do get farmers, often they don't stay for more than a week or two because of the minimal customer numbers. I'd like to consider other market dates, but I'm just not sure that it would solve our problems. I think the demand could be there, but without the farmers and produce to draw in the customers, we have been running in circles for the past four years trying to get the farmers, who'll bring in the customers, who'll bring in the farmers, etc.

Researchers have remarked on the issue of balancing customer and vendor numbers. Burns and Johnson[3] note, 'managers measure the success of their markets by their ability to attract and retain farmer and customer participation' (p. 14). Oberholtzer and Grow[23] observed that markets with fewer vendors also had fewer customers. Hughes and Mattson[25] summarized the relationship between customers, vendors and labor resources for one market: 'More customers result in more vendors, who generate more market fees to pay a coordinator, advertising and other expenses'. They concluded 'This allowed greater input of energy by the coordinator into the market in dealing with vendor issues and market promotion' (p. 8).

Part of the ability to attract customers and vendors rests with the personnel resources the market has. For smaller markets, these resources are minimal. As one market manager inquired:

> Do markets need to reach a sort of tipping point at which the market is doing well enough to support management that then can work to further stabilize the market? And, if so why do some markets reach that point and go on to success while others never reach that point? Also, why do some markets seem to linger in a 'limbo' state for a few years—not growing very much but managing to survive? What causes a market to either make the jump out of 'limbo' or to finally just shut down?

As markets increase in size, they draw both vendors and customers from a larger geographic area—success breeds more success. Burns and Johnson[3] observed, 'it appears that as the size of the market increases, the market becomes more attractive to farmers from a wider geographic area and the retail (customer) trading area also increases' (p. 16). This has implications for smaller markets. As larger markets draw farmers from a larger area, this process may also draw farmers away from markets they perceive as less profitable. As one market manager recounted:

> I heard from several customers that the prices were high, while I heard from several former vendors that customers weren't willing to spend money at the market. This perception on the part of vendors—that there was little money to be made at the market—combined with the reality of the large number of other markets in the Portland area ... made it difficult to attract vendors.

This market manager describes the final season of a western Oregon farmers' market. The market manager participated in the 2002 survey and, at that time, listed the size of the market as 20 vendors.

> The market was located downtown and took place on [a weekday] evening. There were parking problems and tensions with nearby businesses. It was an evening market so it required picking and selling in the heat of the day. Then there was no profit for vendors. Where I would make $120 on Saturday I would only make $30 to $40 [at this market]. The market dropped down to three to four vendors then just stopped.

This account identifies some of the multiple problems this market confronted that led to its eventual closure—lack of parking for customers, tension with local businesses and choice of market day and time. These problems may have reduced customer numbers, which reduced vendor sales, which in turn reduced vendor numbers. In addition, and importantly, the closing of a medium or large size market is rare but we could assume that the number of vendors participating will drop off until the market becomes a smaller size just prior to its failure. This situation is illustrated here with the market dropping from 20 vendors to just three or four vendors prior to closing permanently. It had been a small size market that became a micro size market.

Integration into and support by communities is another theme. This account highlights one market's struggle integrating into a rural community dominated by large commodity-oriented farms:

> In our area row crops predominate, orchards are few and gardens are grown only to meet owner needs and to give produce to neighbors. Our region is totally dependent on irrigation. The oppressive heat which lasts from late June to mid-September doesn't help an outdoor market. It looks pretty bleak. Next year will be the third and last year to attempt a farmers' market.

This market manager describes a lack of community support as a factor in the eventual closing of a market:

> Early in my involvement with the market, I held a meeting for community members. My goal was to find some volunteers who would help out in various aspects of the market. Despite advertising the meeting only 1 potential volunteer showed up. This proved to be symptomatic of the community's lack of direct support for the market. Although many people professed to appreciating having a local farmers' market, hardly anyone except the existing board members were willing to lend any time or support to the market.

Internal issues within a market may distract market organizers from the business of managing the market. For instance, during focus group discussions one manager commented that issues within the market affect its mood:

> When there is stress between the manager and the board, all the manager's energy goes there. It defines the tone. The customers will know if the governance of the market is distressed.

Lastly, a market manager recounted the inertia among market organizers that contributed to the market closing permanently:

> In the end, I grew frustrated with the lack of support and I could see that the market's problems were not going to be solvable without some fairly substantial changes which the board was unwilling to make.

The quantitative data related to markets that fail describes a downward spiral of interrelated factors of small market size, inadequate product, low revenues, poorly compensated managers and high manager turnover that are seemingly impossible to correct once past a particular point. The accounts from managers of failed markets describe a complex and nuanced background of issues internal and external to the individual market that ultimately lead to or trigger the downward spiral.

## Summary, Discussion and Recommendations

It is important for market organizers, vendors and the food advocates and academics that support them to recognize that markets—especially new markets—are more fragile than many have assumed. The analysis suggests a sequence of market decline and failure. Failing markets are small, already at a disadvantage in terms of revenue and personnel resources due to their size. Causes leading to the market's decline appear to be individualized, complex issues that are internal and/or external to the market. These markets enter a downward spiral of declining numbers of customers and vendors, intensifying the problem of inadequate product and leading to even fewer customers. With limits to how much effort volunteers are able to provide before burning-out, the low revenues to the market interfere with its ability to use paid personnel to stabilize the market. All this occurs in a short period of time; in as little as one year and less than four years for the vast majority of markets that fail.

Success and failure should be viewed as a continuum rather than an either/or condition. Along the continuum between the extremes are markets that are under-performing but have not failed. Some of these markets may have thrived at one time and have not been able to adapt to changing conditions or have encountered a crisis. Other markets may not ever have thrived and continue to exist in the state of 'limbo' described by one manager. Can these markets be revitalized? The accounts from managers of markets that failed suggest there are combinations of issues unique to each of the markets that increased their vulnerability. More examination of the very complex interactions within communities and markets that lead to farmers' market success or failure is needed.

### *Areas of risk*

There are two areas of risk associated with characteristics of markets and market managers. Market organizers should be concerned about these areas of risk particularly if they are present in combinations. These areas of risk reiterate the connection between market administrative revenue and the ability to hire paid personnel to manage market operations.

**Small markets, markets becoming smaller and new markets.** Smaller markets are more at risk of failure than larger markets. Since they have fewer vendors, smaller markets are vulnerable to descending quickly into a crisis by a drop in vendor numbers and thus, suffering the repercussions of a lack of products, fewer customers and low administrative revenue. In addition to having fewer fee-paying vendors, these markets also charge lower stall fees than larger markets and thus face two challenges to generating administrative revenue. Markets that fail may have been small to begin with or may have been larger but have become smaller through a period of decline. Therefore, any market that is progressively declining in size should be of concern. These markets will also be collecting less money from vendors and will have a difficult time maintaining management staff. As a separate but related issue, new markets face a higher probability of failure. This is particularly true in their first year and up to their fourth year. Although older markets are not entirely safe from failure, their failure rate is low.

**Over-worked managers, under-compensated managers, inexperienced managers.** Manager turnover on an annual basis is high among markets in general at 30% and higher among markets that fail at 46%. Some areas of concern associated with farmers' markets in general include whether and how much managers are paid, thresholds for volunteer manager effort and size of market, new markets and inexperienced managers and manager turnover. Most managers of markets that failed were volunteers or were paid a low salary. These managers are more commonly associated with smaller markets. In fact, there are no volunteer managers associated with medium or large size markets. This likely indicates a limit to the capacity for volunteers to manage markets over a specific size. There is also a correlation between new markets and inexperienced managers, a potentially risky combination.

### *Recommendations*

Based on the analysis above, here are two broad recommendations for market managers, boards of directors, vendors and the food advocates and academics that work with them. The recommendations are supported by the research findings and can be implemented at the local community or individual market level.

**Recommendation 1: Plan new markets carefully to assure success.** Market organizers should spend considerable time deciding whether and how to open a new market. Better planning and promoting *before* a new market is opened may help with some of the issues that arise during the critical first year of operation. An important part of the planning process is setting a goal for market size

in general or a goal by year so that cash flow can match the scale of the market and appropriate management can be provided. Planning for size is the first step in creating a viable organization that will endure the challenges and conflicts that occur with growth. Organizers should concentrate on making well-informed decisions on market organization and, most importantly, garner community support in order to avoid the issues identified by managers of markets that failed.

Market size will be influenced by community population density, population subculture (interest in purchasing local food and the experience of an open air market), and other factors that influence the scale of a market from the demand side. From the supply side, local farm settlement pattern (number and type of small farms), agro-ecozone (soils, climate, etc.) and other factors influence the size of the market, as well. Organizers should carefully assess whether there is sufficient population to support a market and whether there are sufficient farmers to support a market.

Training programs for new managers and boards of directors may reduce the number of markets that close after a brief life and reduce manager turnover in operating markets. In some instances, volunteers can substitute for paid staff resulting in lower operating expense for the market. There are limitations to what volunteer managers can achieve. A good recommendation for organizers is to have a plan in place for the transition of a volunteer to a paid manager position as market size approaches the mid-teens in numbers of vendors and requires the manager to work more than seven hours per week during the market season. Consistent, well-trained or experienced management that matches the scale of the market and is fairly compensated may prevent the kind of problems that weaken a market and lead to a downward spiral.

**Recommendation 2: Some markets should pursue community financial support.** Some smaller markets will always have difficulty generating sufficient administrative revenue to support a paid manager and other important market functions. These markets may be viable only through financial or labor resources provided through other civic or government entities. There are precedents for this in Oregon. The Oregon market manager survey indicated that in 2002 six markets were connected with government and non-government organizations. These organizations support their farmers' markets by providing a salaried staff member for management and other amenities. Since farmers' markets have been shown to be an important part of a local economy and an enhancement to the quality of community life, there is ample justification for government and economic development sector support.

Faith, environmental and health organizations are other potential community sponsors. Many faith groups are involved in food security and social justice issues that link well with developing local food economies. Many environmental organizations point to locally produced food as good for the environment but likely are not directly involved in the financial support of individual farmers' markets. There are instances of health care providers offering sponsorship or start up support for farmers' markets. This offers a model for private sector support that holds some potential for providing markets in some communities.

Access to financial and other resources is a national policy-related issue with significant impacts on farmers' markets, particularly small markets. Public funds support commodity agricultural production and the global trade of food products, but similar resources are not made available to support local agricultural markets. These circumstances are the result of political decisions at the national level. As Lang[26] points out, food systems are the outcome of policy and political choices. Should future national political decisions benefit local markets, the course of agricultural development in the US could be significantly altered.

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# Adding value in the organic sector: Characteristics of organic producer–handlers

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## Abstract

Sales of organic food have soared over the past decade. Although nearly all organic commodities pass through the hands of at least one intermediary on the way from the farmer to the consumer, there is a dearth of literature examining organic food marketing, especially for the middle section of the supply chain. This paper uses new survey data on organic intermediaries (organic handlers) to characterize firms that are certified to both handle and produce organic foods, or organic producer–handlers. Because of their direct link to the production level, the producer–handler has the potential to provide insight into value-added activities in the organic sector. A logistic regression is estimated in order to identify characteristics that make it more likely that a firm would be both a certified organic handler and a certified organic producer, while survey results are also used to describe some of the main challenges these producer–handlers face in handling their products. Organic producer–handlers ranked problems with ingredient procurement and supply and international trade issues as the highest barriers to growth. The model indicated that with few exceptions, many of the operational and procurement characteristics of organic producer–handlers are comparable to the entire organic handling population. However, those facilities dedicated solely to organic handling and those certified longer are more likely to be organic producer–handlers. Use of direct markets by organic handlers has the most robust relationship in the model, although marketing to natural products independent retailers and wholesalers are also important.

**Key words:** organic, handlers, producers, marketing, procurement, logistic regression

## Introduction

Sales of organic food have soared over the past decade, from $3.6 billion in 1997 to $15.7 billion in 2006. It is estimated that organic foods now make up 2.5% of all food sales[1,2]. This dramatic growth has inspired much talk about the organic market's transition from niche to mainstream, and it is true that organic products seem ubiquitous; most conventional supermarkets now carry organic food and many have their own organic store brands. The potential for profits has not gone unnoticed by big business, and even Walmart has tried to capitalize on the market, albeit with limited success.

Growth in the organic sector has provided numerous opportunities for all agents along the supply chain, from organic producers and handlers, to retailers. In some circumstances, agents work at multiple levels of the supply chain. For example, organic farmers add value to their products, acting as both producers and intermediaries. These entities may be trying to capture part of the downstream value of their agricultural commodity, or maintain a certain part of the growing market through product differentiation, by (for example) providing locally grown organic food or organic milk from pasture fed cows.

Although nearly all organic commodities pass through the hands of at least one intermediary on the way from the farmer to the consumer, there is a dearth of literature examining organic food marketing, especially for the middle section of the supply chain. To gain insights into organic supply chain dynamics, a nationwide survey of organic processors, manufacturers and distributors (called organic handlers) was undertaken in 2005 by the US Department of Agriculture's Economic Research Service (ERS). The survey population included all facilities certified to handle organic products in 2004.

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A subpopulation of those surveyed includes firms that are also certified as organic producers, or organic producer–handlers. These handlers, because of their direct link to the production level, have the potential to shed light on value-added activities in the organic sector. This paper uses new data to characterize firms that are certified organic producer–handlers, examining their operations and marketing and procurement practices. A logistic regression is estimated in order to identify characteristics that make it more likely that a firm would be both a certified organic handler and a certified organic producer. Survey results also describe some of the main challenges these producer–handlers face in handling their products.

## Background

Organic handlers are certified to handle organic products in accordance with the National Organic Standards. These intermediaries are packing and shipping, manufacturing and processing, and distributing, wholesaling, and brokering organic products, playing a central role in the organic industry. Their functions are similar to those of their conventional counterparts, with the added requirement that organic integrity of all products must be maintained as the products move along the supply chain, as specified by the National Organic Standards.

The National Organic Standards define organic handling practices to include mechanical or biological methods, including but not limited to cooking, baking, curing, heating, drying, mixing, grinding, churning, separating, distilling, extracting, slaughtering, cutting, fermenting, eviscerating, preserving, dehydrating, freezing, chilling, or otherwise manufacturing, and the packaging, canning, jarring, or otherwise enclosing food in a container that may be used to process an organically produced agricultural product for the purpose of retarding spoilage or otherwise preparing the agricultural product for market. Entities that handle organic products are exempted from organic certification if they have gross organic sales under $5000.

The population of interest for this study—organic handlers that are also certified to produce organic products—is diverse, and includes, for example, farmers that might be selling jams and jellies at a farmers' market, manufacturing cheese from milk, or processing meat from animals raised on the farm. It also includes maple syrup producers in the Northeast, large produce packers and shippers on the Pacific Coast, grain elevators in the Midwest, various producer cooperatives, as well as wineries and organic bakeries. These organic handlers may be handling products from only their own farm, or procuring from other farms and handlers as well. In other words, the group is not merely organic growers adding value to products from their own farm, but also includes handlers that are procuring products from many suppliers with their farm as only one source.

Both conventional and organic producers add value to farm products to capture more of the downstream value for agricultural commodities. Others may use value-added agriculture as a way to diversify farm sales and marketing outlets. In the organic sector, adding value to products may also be a way for organic producer–handlers to maintain a certain part of the growing market through differentiation. In addition, they may be trying to meet some of the consumer preferences for aspects that are not captured in the organic label, such as supporting small farms, or local production and manufacturing. Consumer polls indicate that consumers are increasingly interested in products that are locally produced[3,4] because of perceived product freshness and support for local agriculture. Consumer awareness of the energy costs involved in transporting food long distances to supermarkets is also growing.

While the size of value-added agriculture is difficult to measure due to the range of activities it encompasses, anecdotal information suggests an increase in these activities in the United States. A portion of value-added activities can be measured through the Census of Agriculture's reporting of the value of agricultural products sold direct to individuals; these numbers have increased substantially over the 15 years ending with the 2002 Census, from $404 million in 1982 with 86,500 farms selling direct, to $812 million in 2002 with almost 117,000 farms.

Although it represents just a portion of value-added activities, direct sales are important in the organic sector in that a higher proportion of total organic sales are made through direct markets, such as farmers' markets, roadside stands and mail order sales, than for conventional sales[5]. A 2001 survey of organic producers by Organic Farming Research Foundation[6] indicated high use of direct markets, although it varied by commodity. For instance, 80% of respondents that produced vegetable, herb, floriculture, mushroom and honey products used some type of direct markets as a marketing avenue, with an estimated volume of 13% of products sold this way. Direct marketing was used for about 28% of grain and field crop sales (11% of volume), 58% of fruit, nut and tree products sales (11% of volume) and 54% of livestock product sales (26% of volume).

Information on organic producer–handlers has been unavailable until now, requiring researchers to examine handlers and producers separately. While data on organic handlers is scarce, preventing systematic studies of trends in the organic marketing supply chain, growth in the number of organic handlers is apparent. Estimates in the early to mid-1990s showed substantial growth (20–39% a year) in the handling sector and the number of certified handlers was placed at 694 in 1995[7]. By 2004, approximately 2790 facilities were certified as organic handlers.

More is known about the organic production sector, although actual production data are unavailable. Certified organic acreage, used to approximate production potential of US organic farms, quadrupled from almost 1 million acres in 1992 to 4 million in 2005[8], and the number of certified operations increased from 3587 to 8493. In 2005,

certified organic cropland and pasture accounted for 0.5% of the total US cropland and pasture, although the share is much higher in some crops, such as vegetables at nearly 5% and fruit at about 2.5%.

A handful of studies has focused on organic producers who add value to their products, although these studies are based on surveys with a narrow scope. Austin and Chase[9] surveyed organic growers, 'value-added organic growers' and organic processors in Florida. Their study, based on a small sample, found that value-added organic growers in Florida were most likely to be packers and shippers of the farm's own products, selling primarily to local markets within 60 miles of the farm or to the Florida market. The processors in the study were most likely processors of citrus juice selling nationally and internationally. Bingen et al.[10] surveyed organic processors in Michigan on 2006 practices, and (with 39 respondents) found that most vegetable processors sell primarily in local and state markets, while livestock processors sell equally in local, state, regional and national markets. They also found that processors use direct-to-consumer and wholesale markets almost equally.

Data from the 2001 OFRF survey of organic producers[6] show that 29% of respondents (305 farmers) reported gross sales derived from value-added products processed by their farm or for their farm prior to product sale. In the product categories (herbs, vegetables, fruit and tree nuts, grains and livestock products including milk), the products with the highest number of reports for value-added products from the farm included dried herb, ornamentals and greenhouse products, salad mixes, preserves, cleaned, dried and/or bagged grains and fresh and frozen meats. Unpublished data from a recent 2005 survey of 141 organic producers in the Four Corner States (Arizona, Colorado, New Mexico and Utah) showed a similar percentage of organic producers (34%) reporting some organic sales (an average of 20% of all organic sales) through processed or value-added products. Contrasting these numbers, unpublished data from a 2007 survey of 195 Minnesota organic producers found that only 8% of producers had sales of value-added products, with most of it going through direct sales at the farm or to retail stores, or through other outlets.

## Data and Methods

A unique, new dataset underlies this analysis: the results of a nationwide survey of organic processors, manufacturers and distributors (called organic handlers) of 2004 practices, by USDA's ERS. The project was funded by USDA's Risk Management Agency, and carried out with collaborators from the University of Georgia and Pennsylvania State University.

The survey was drafted with input from stakeholders in the organic sector, including certifiers, farmers, processors, academics and representatives from non-profit organic organizations. The final survey instrument was developed by ERS in consultation with Washington State University's Social and Economic Science's Research Center (SESRC), and consisted of 59 questions covering: (1) operational and business practices (e.g., facility function, products produced and labels used); (2) basic characteristics of handling facilities (e.g., gross sales, size of facility and years certified organic); (3) relationships with customers (e.g., marketing outlets used and distance to markets); and (4) relationships with suppliers, including types of suppliers, purchase arrangements (contract versus spot market), as well as assistance provided to suppliers and attributes and requirements of suppliers.

**Table 1.** Regional characteristics of organic producer–handlers and all organic producer and handlers, 2004.

| Region | Organic producer–handlers | Organic producers | Organic handlers |
|---|---|---|---|
| | Percent of US total | | |
| Pacific | 40 | 31 | 42 |
| Northeast | 18 | 20 | 16 |
| Mountain | 13 | 8 | 9 |
| Lake States | 10 | 15 | 11 |
| Corn Belt | 6 | 12 | 9 |
| Southeast | 3 | 2 | 2 |
| Appalachia | 2 | 2 | 3 |
| Northern Plains | 2 | 6 | 3 |
| Southern Plains | 2 | 3 | 3 |
| Alaska and Hawaii | 2 | 2 | 1 |
| Delta | 1 | 0.2 | 1 |

The survey was sent to the population of all certified organic handling facilities in 2004. Because of the way in which most handlers hold their organic certificates (at the facility level), each facility, whether it belonged to a larger company (30% reported multiple locations in the company) or was independent, was counted separately. SESRC administered the survey in late 2005 and early 2006, using the Tailored Design Method (TDM)[11]. All firms were pre-notified by postcard of the survey. The survey was sent by first class mail, with a $5 incentive, and was followed by multiple carefully timed contacts, including two postcards, a subsequent questionnaire mailing and phone contacts. Of the total population, 1393 organic handlers completed a 16-page mail survey, representing a 63% return rate. Of these, 347 (25% of survey respondents) reported that they held dual certification as an organic producer and handler.

Like all organic handlers, organic producer–handlers are concentrated in the Pacific region (Table 1)[8,12]. The Northeast, Mountain, and Lake States also have a significant number of producer–handlers as well, and for the most part these concentrations mirror those of all organic handlers. Not surprising given the dominance of produce in the organic industry, fruits and vegetables were the top two commodities sold by organic producer–handlers in 2004, followed by spices and herbs, grains and feed, and beans/legumes/peas.

As with handlers, the Pacific and Northeast are the top regions with certified organic producers, and the overall

regional ranking is also very similar. The Northeast has a slightly higher percentage of producers than handlers, perhaps reflecting the presence of fewer national produce distributors in this region than in the Pacific. The Mountain, Corn Belt and Plains regions also have a relatively smaller percentage of handlers. Fewer handlers may be needed to process the grains and dairy that predominate in these regions.

Summary statistics for the variables used in this study are shown in Table 2. The operational variables include facility size, the number of years certified organic, function of the facility and percent of gross sales as organic. The smallest organic handlers are likely excluded from the dataset because handling operations that have under $5000 in gross annual income from organic sales are exempted from certification. The number of years certified organic is a continuous variable. Discrete variables include whether a facility was 100% organic or a mixed facility; the vast majority of facilities are mixed facilities, handling both conventional and organic products. The function of a facility (e.g., manufacturer, wholesaler or distributor, broker, or packer–shipper) was divided into four dummy variables; at least 50% of the facility's function had to be in one of these categories to be included. Manufacturing/processing was the most widely reported function by all handlers. Finally, firm size was divided into four categories based on gross sales (both organic and non-organic), with most facilities having up to $15 million in sales, although organic producer–handlers reported gross sales up to only $1 million at a higher rate than all handlers.

Marketing characteristics include the use of different market outlets and labeling practices. The possible marketing outlets are: wholesaler and distributor, manufacturer or processor, natural product supermarkets, independent natural product stores, direct markets and conventional supermarkets. In the survey, handlers reported the percent of their product marketed in those five markets. For the econometric analysis, we developed five discrete variables based on whether a facility uses the outlet for more than 20% of gross organic sales (thus, the analysis allows for the fact that handlers may market to more than one outlet). Five labels for organic products were also included, and were coded as dummy variables. The first is an organic label (e.g., USDA logo or certifier's logo), as well as four other types of labels commonly used on alternative agricultural products: socially responsible (such as fair trade), eco-label, local label and a free-range or pasture label.

Data on procurement practices were also included in the analysis, where procurement refers to the purchase of raw materials, agricultural commodities and other products by handlers, who either manufacture, process, or distribute the products. The variables included are the percent of the facility's procurement that was organic (continuous variable), two dummy variables approximating the distance for procuring organic products (more than 50% of their procurement from local or international markets), as well as three dummy variables for the use of different types of suppliers (i.e., growers and grower cooperatives, manufacturers/processors and distributors).

The descriptive statistics show that organic producer–handlers differ from the overall handler population in a few striking ways: they have been certified organic, on average, for 1 more year; they have a higher share of firms that are 100% organic; have a greater percent of small firms; make greater use of direct markets and procure a greater share of organic products.

## Results and Discussion of Research Findings

Two tracks were taken in analyzing the survey data. First, the survey data were used to determine which factors certified organic producer–handlers viewed as obstacles to growth, with a comparison to previous studies. A logistic regression model estimated which factors influenced the likelihood of certified organic handlers choosing to be certified as producers as well.

### *Primary barriers to growth faced by organic producer–handlers*

Although organic handlers have benefited from the overall growth of the organic industry, they have faced a number of constraints to growth since the late 1990s. A few studies illustrate the main concerns. One of the top challenges for the industry has been procuring ingredients, which includes the spectrum of issues relating to ingredient procurement, such as ingredient costs, quality consistency, shortage of ingredients and other supply problems[1,13]. Distributors similarly report difficulty finding large enough quantities of organic products to distribute to retailers, as well as locating organic producers as sources for products they deliver[7]. Distribution channels also present a challenge for manufacturers; in the past, transportation and the high cost of distribution have been cited as impeding growth of the sector.

The survey included an open-ended question about the primary challenges faced in handling certified organic products. The answers fell into a number of categories, many similar to those made by all organic handlers, but some addressing production areas as well. Not surprising given previous research, the number one area of concern raised was procurement. Five percent of the producer–handlers noted that there are challenges with the availability of organic ingredients or growers, while 3% noted problems with the cost of supply. Eight producer–handlers reported challenges with procuring a consistent quality of supply, two reported problems with obtaining year-round supply, and one reported problems with buying in large quantity.

Consistent with previous industry reports on supply shortages in the organic sector, a fairly large number of

**Table 2.** Descriptive statistics of variables used in the logistic regression: organic producer–handlers and handlers.

| | Variable | Definition | Producer–handlers ($n = 347$) Mean (SD) | Handlers ($n = 1393$) Mean (SD) |
|---|---|---|---|---|
| **Operational characteristics** | | | | |
| *General* | Years certified* | Number of years certified organic | 5.1 (5.5) | 4.0 (4.5) |
| | Organic only* | 1 if facility reported 100% of gross sales as organic | 0.35 (0.48) | 0.15 (0.36) |
| *Function* | Manufacturer | 1 if reported manufacturing/processing as a function for more than 50% of gross organic sales | 0.45 (0.50) | 0.44 (0.50) |
| | Wholesaler | 1 if reported wholesaling/distributing as a function for more than 50% of gross organic sales | 0.13 (0.33) | 0.12 (0.33) |
| | Broker | 1 if reported brokering as a function for more than 50% of gross organic sales | 0.02 (0.15) | 0.02 (0.14) |
| | Packer | 1 if reported packing/shipping as a function for more than 50% of gross organic sales | 0.11 (0.31) | 0.08 (0.27) |
| *Size* | Small* | 1 if gross sales up to $1 million | 0.61 (0.49) | 0.44 (0.50) |
| | Medium* | 1 if sales over $1 million to $15 million | 0.23 (0.42) | 0.32 (0.47) |
| | Large* | 1 if sales over $15 million to $100 million | 0.10 (0.30) | 0.14 (0.34) |
| | Xlarge | 1 if sales over $100 million | 0.03 (0.17) | 0.03 (0.17) |
| **Marketing characteristics** | | | | |
| *Market use* | Market to wholesaler | 1 if marketed more than 20% of gross organic sales through wholesalers, brokers, distributors and repackers | 0.47 (0.50) | 0.42 (0.49) |
| | Market to NPI* | 1 if marketed more than 20% of gross organic sales through natural product independent or cooperative stores | 0.19 (0.39) | 0.13 (0.33) |
| | Market to NPS | 1 if marketed more than 20% of gross organic sales through natural product supermarkets (e.g., Whole Foods) | 0.18 (0.38) | 0.14 (0.35) |
| | Markets direct* | 1 if marketed more than 20% of gross organic sales through direct markets (e.g., farmers' markets and on-farm sales) | 0.23 (0.42) | 0.10 (0.30) |
| | Market to conventional | 1 if marketed more than 20% of gross organic sales through conventional grocery markets or discount stores | 0.09 (0.29) | 0.10 (0.30) |
| *Label use* | Organic label* | 1 if uses either USDA organic or certifier's label | 0.79 (0.41) | 0.71 (0.47) |
| | SR label* | 1 if uses socially responsible label | 0.03 (0.16) | 0.08 (0.26) |
| | Eco label | 1 if uses eco-label | 0.04 (0.20) | 0.04 (0.19) |
| | Buy local label* | 1 if uses regional or local label | 0.14 (0.35) | 0.08 (0.27) |
| | Free-range label* | 1 if uses a free-range or pasture based farming label | 0.06 (0.24) | 0.03 (0.18) |
| *Census-direct sales* | Direct sales State | Percent of gross agricultural sales that are direct-to-individual sales per State from 2002 Agricultural Census | 0.79 (1.04) | 0.76 (1.03) |
| **Procurement characteristics** | | | | |
| | Percent procure organic* | Percent of facility's procurement that is organic | 58.8 (42.5) | 38 (40.7) |
| *Procurement distance* | Procures locally | 1 if purchases of more than 50% of organic procurement (by volume) locally (within a 1 h drive) | 0.21 (0.41) | 0.17 (0.38) |
| | Procures internationally* | 1 if purchases more than 50% of organic procurement (by volume) internationally | 0.07 (0.25) | 0.15 (0.36) |
| *Supplier use* | Procures from growers | 1 if procures from individual growers or marketing/growers' cooperatives | 0.41 (0.49) | 0.39 (0.49) |
| | Procures from processors | 1 if procures from manufacturers or processors | 0.20 (0.40) | 0.26 (0.44) |
| | Procures from distributors | 1 if procures from wholesalers, distributors, agents or brokers | 0.19 (0.40) | 0.21 (0.41) |

* Indicates differences in means that are statistically significant; $t$-values with significance at $\alpha = 0.05$ level.

organic producer handlers—17%—reported critical *shortages* of supply, with many reporting more than one product they need in short supply. However, only 6% of the population of organic producer–handlers reported critical *oversupply* of organic products to their customers in 2004.

Among the organic producer–handlers who experienced product shortages, short supplies were reported across all major food categories. Leading the list of shortage products were fruit, grains, feeds, soybeans, cheese and milk/milk products, vegetables and meat/meat products. Twenty-eight percent of organic producer–handlers also reported difficulty in securing organic ingredients at some point in 2004. Those ingredients reported the most included fruit, seeds, grains, feed and soybeans for feed, vegetables, milk and milk products, herbs, spices and extracts. Another indication of limited supply was whether the producer–handler was granted a commercial non-availability allowance in 2004, allowing for the use of a non-organic ingredient in an organic product if the ingredient was not commercially available in organic form. While 6% of organic producer–handlers reported that they had an allowance, this was a lower rate than the 9% for all handlers.

Another top challenge for organic producer handlers was international trade, both imports and exports, as well as the restrictions, costs and paperwork of trade; this was raised by 5% of the population. Five percent of producer–handlers also reported that the organic certification process and the paperwork involved in certification are too burdensome or costly, or it is too difficult to keep up with the organic standards. A couple of producer–handlers felt that there was pressure from large-scale growers to lower the standards, while three reported that they thought there was a need for stricter enforcement of the rules and regulations.

Financial issues also ranked high among the challenges of producer–handlers: 4% reported that overall financial challenges, including financing, were a problem; while facilities also reported problems with cash flow, high labor costs and high transportation costs. Finally, production challenges are unique to this set of handlers because they also undertake production activities. Three percent reported overall production limitations or problems with weather, and several suggested that the price of production was too high for the return. These concerns echo the ones mentioned in focus groups with organic producers across the country[14].

## Factors influencing choice of dual certification

The decision to be certified as both an organic producer and handler can be modeled as a discrete choice where the dependent variable, $y_i$, takes on the value of 0 if the intermediary is certified just as a handler or the value of 1 if the handler is certified as a producer as well. Based on the logistic distribution, the probability of being certified as a producer and a handler is:

$$\Pr\{y=1\} = \frac{e^{\beta_j' x_i}}{1+\sum_{k=1}^{J} e^{\beta_j' x_i}}, \quad \text{for } j=1, \tag{1}$$

while the probability for being certified as just a handler is:

$$\Pr\{y=0\} = \frac{1}{1+\sum_{k=1}^{J} e^{\beta_j' x_i}}. \tag{2}$$

Either probabilities ($P$) or the odds ratio, $P/(1-P)$, can be estimated in the logistic model. The odds ratio was chosen rather than probabilities for ease of exposition. When estimating odds ratios, the estimated coefficient of an explanatory variable provides the odds that a producer–handler markets to wholesalers, for example, relative to a handler. An estimated odds ratio greater than 1 indicates producer–handlers are more likely to market to wholesalers, while an estimated odds ratio less than 1 indicates that producer–handlers would be less likely to market to wholesalers. An estimated odds ratio of 1 indicates that both groups are equally likely to market to wholesalers.

The variables that were thought to influence the decision to both handle and produce organic products include operational characteristics of the facility, marketing behaviors and procurement practices; these data were from the ERS survey of organic handlers. Other data were also used in the analysis, including 2002 Agricultural Census data on direct marketing, as well as production data on organic agriculture.

A priori, it was expected that facilities certified organic for a longer period of time or dedicated organic facilities (in contrast to mixed facilities) would be more likely to be organic producer–handlers. In addition, the descriptive statistics and presumptions about the population pointed to other potentially important factors: firm size and the function of packer–shipper.

The results of the econometric model (Table 3) confirm some assumptions. Firms that were more likely to be certified as a producer–handler were certified organic longer, had dedicated organic facilities (100% organic sales), marketed to wholesalers, direct marketed, or marketed to independent natural food stores. While use of an organic label by an organic handler, either the USDA logo or a certifier's logo, does not influence the likelihood that a handler would also raise organic products, use of an eco-label, a 'buy local' or 'buy regional' label, or free-range label increases the likelihood of being an organic producer–handler. The final explanatory variable that had an impact on the probability of being a producer–handler was the share of organic products procured; the higher this share, the greater the odds of being a producer–handler.

The use of direct markets (e.g., farmers' markets, CSAs and on-farm sales) for more than 20% of organic sales was a strong predictor, with those in this population being 250% more likely to be an organic producer–handler. Agricultural Census data from 2002 confirmed other relationships with direct marketing. Using direct-to-individual sales (a proxy for direct marketing sales) as a percentage of

**Table 3.** Logistical regression analysis of organic producer–handlers' characteristics.

| Variable | Exp(B) (Odds ratio) | *P* value | Estimate |
|---|---|---|---|
| Intercept | | < 0.0001 | −2.6603 |
| Years certified* | 1.043 | 0.0307 | 0.0423 |
| Organic only* | 1.852 | 0.0248 | 0.6161 |
| Manufacturer* | 0.721 | 0.1011 | −0.3270 |
| Wholesaler* | 0.557 | 0.0567 | −0.5845 |
| Broker | 1.987 | 0.2445 | 0.6866 |
| Packer | 0.972 | 0.9325 | −0.0286 |
| Small | 1.783 | 0.2089 | 0.5784 |
| Medium | 1.010 | 0.9836 | 0.00970 |
| Large | 1.360 | 0.5441 | 0.3076 |
| Xlarge | 1.588 | 0.4881 | 0.4624 |
| Market to wholesaler* | 1.591 | 0.0174 | 0.4642 |
| Market to NPI* | 1.572 | 0.0916 | 0.4527 |
| Market to NPS | 1.163 | 0.5654 | 0.1511 |
| Markets direct* | 3.502 | < 0.0001 | 1.2533 |
| Market to conventional | 1.206 | 0.5567 | 0.1872 |
| Organic label | 1.408 | 0.1416 | 0.3421 |
| SR label* | 0.127 | 0.0003 | −2.0647 |
| Eco label* | 2.809 | 0.0280 | 1.0329 |
| Buy local label* | 1.775 | 0.0950 | 0.5739 |
| Free-range label* | 2.462 | 0.0502 | 0.9009 |
| Direct sales State* | 1.186 | 0.0565 | 0.1707 |
| Percent procure organic* | 1.009 | 0.0013 | 0.00934 |
| Procures locally | 1.065 | 0.7800 | 0.0631 |
| Procures internationally* | 0.486 | 0.0140 | −0.7216 |
| Procures from growers | 0.911 | 0.6446 | −0.0931 |
| Procures from processors | 0.735 | 0.1344 | −0.3074 |
| Procures from distributors* | 0.692 | 0.0916 | −0.3686 |

$N = 909$.
* Indicates statistical significance ($P < 0.10$).
Note: An odds ratio of 1 indicates that the variable is equally likely in both groups. An odds ratio greater than 1 indicates that the variable is more likely in the producer–handler group than the overall handler population, while an odds ratio less than 1 indicates that the variable is less likely in the producer–handler group.

| | $X^2$ | *df* | *P* |
|---|---|---|---|
| Overall model evaluation | | | |
| Likelihood ratio | 183.6868 | 27 | <0.0001 |
| Goodness-of-fit test | | | |
| Hosmer and Lemeshow | 6.4342 | 8 | 0.5987 |
| Nagelkerke $R^2 = 0.2792$ | | | |
| Predicted probabilities | | | |
| $c = 0.781$ | | | |

Classification table

| Correct | | Incorrect | | Percent correct |
|---|---|---|---|---|
| Event | Non-event | Event | Non-event | |
| 128 | 539 | 166 | 76 | 73.4 |

Probability level = 0.24; sensitivity = 62.7%; specificity = 76.5%; false positive = 56.5%; false negative = 12.4%.

all agricultural sales in a State, each increase in percent increases the likelihood that the handler will be an organic producer–handler by almost 20%. Thus, New Jersey's organic handlers are 41% more likely to be an organic producer–handler (based on 2.6% of the State's all agricultural sales consisting of direct marketing sales) than are Utah's organic handlers (0.6%).

A higher percentage of total procurement as organic influences the likelihood of being a producer–handler. Although the change per percentage point is small (<1%), the likelihood of being an organic producer–handler is slightly greater at higher percentages of organic procurement. For example, if a facility obtains 75% of total procurement as organic, that facility is 96% more likely to be an organic producer–handler. This result is not surprising given that dedicated organic facilities are also a significant factor in the model.

Firms that were less likely to be certified as both a handler and producer were manufacturers or wholesalers, used the socially responsible label, and procured from international markets. Further, the use of distributors for procurement purposes made the facility less likely to be an organic producer–handler.

The a priori notion that packers and shippers were more likely to be producer–handlers did not bear out in the analysis. Another assumption, that small firms would be more likely to be organic producer–handlers, was also not supported by the analysis. The use of total gross sales—conventional and organic—instead of organic sales only (which was not available in this survey), may be a complicating factor, masking some causality. In addition, some of the smaller certified organic producers that sell value-added products, such as jams and jellies, may opt not to certify and label those products as organic because of the additional expense and paperwork involved, particularly if they are selling in direct markets where they may have personal communication with their customers.

It was expected that variables approximating organic production would be significant predictors. These data consist of 2005 organic acreage and farm numbers[8], which were translated into State averages for organic farm size and the percentage of farms and farmland that are organic per State. All were found to be insignificant and thus excluded from the model.

The model was evaluated using a likelihood ratio test, which was significant at $P < 0.001$, and Hosmer and Lemeshow's goodness-of-fit test, which was insignificant. Both of these tests suggest that the model has a fairly good fit to the data. The *c* statistic (which varies from 0.5, the model's predictions are no better than chance, to 1.0 and is the percent of all possible pairs of cases in which the model assigns a higher probability to a correct case than to an incorrect case) of 0.781 and the percent correctly classified (73.4%) indicate that the predicted probabilities of the logistic regression fairly consistently agree with the actual outcomes.

## Conclusion

Since 1990, growth in retail sales of organic products and certified organic farmland has been remarkable. Hidden behind the expansion of organic farmland and retail sales is

the handler of organic products. This agent plays a crucial role in maintaining the integrity of organic products as they move along the supply chain from farm to consumer, from local, national and international locations. How well they have fared is not apparent to the casual (or even not-so-casual) observer of the organic sector. This paper is one of the first attempts to examine the challenges faced by handlers, specifically one type of handler—facilities that hold dual certificates to produce and handle organic products. The producer–handler has the potential to provide insight into value-added activities in the organic sector, through their direct link to the production level; thus, we examined which characteristics made it more likely that a firm would choose to certify as both a handler and producer.

To date, the middle segment of the organic supply chain has been little studied. New data from a survey of all certified organic handlers indicate that organic producer–handlers face barriers to growth similar to the overall organic handler population and corresponding to past research. Procurement of ingredients and supply ranked as a top concern, as well as international trade issues.

Similar to the population of organic handlers, organic producer–handlers are a diverse group handling the entire range of agricultural commodities. With few exceptions, many of their operational and procurement characteristics are comparable to the entire organic handling population. Operationally, facilities dedicated solely to organic handling and those certified longer are more likely to be organic producer–handlers. The converse is true of handlers that undertake manufacturing or wholesaling functions. Most producer–handlers are using suppliers in some way to procure products and ingredients. However, the only significant relationships found were those related to the percentage of procurement that is organic, and procurement through imports or distributors.

The types of outlets producer–handlers market in differ from those used by the overall population of handlers. Use of direct markets by organic handlers has the most robust relationship, with Agricultural Census data also revealing relationships between the use of direct markets by all farmers in a State and the likelihood that a handler in that State would be a producer–handler. Marketing to natural products independent retailers and wholesalers is also important to the population. Labeling practices play a role as well. Although the use of organic labels by producer–handlers differs little from the general handler population, some notable exceptions were the use of 'buy local' and eco labels. Thus, organic producer–handlers seem to be touting the locally grown and environmental characteristics of their products significantly more than all handlers. Certified organic producers who also have handler certification and are embedded in organic farm communities may be poised to provide products that are both local and organic when that market takes off.

Value-added agriculture has traditionally made it possible for farmers to differentiate their products in a competitive market, presumably increasing their profits. As the organic industry grows and questions arise as to whether organic firms will need to grow larger to remain viable, more organic farmers and handlers may decide to gain certification to produce and handle. The results of our research point to the challenges these producer–handlers might face concerning procurement. Maintaining a dedicated organic facility and marketing direct to consumers, to natural product independent retailers and to wholesalers may be the best long run strategy for these firms.

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# Organic premiums of US fresh produce

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## Abstract

The study uses the 2005 Nielsen Homescan panel data to estimate price premiums and discounts associated with product attributes, market factors, and consumer characteristics, focusing on the organic attribute for five major fresh fruits and five major fresh vegetables in the United States. The results suggest that the organic attribute commands a significant price premium, which varies greatly from 13 cents per pound for bananas to 86 cents per pound for strawberries among fresh fruits and from 13 cents per pound for onions to 50 cents per pound for peppers among fresh vegetables. In terms of percentages, the estimated organic price premiums vary from 20% above prices paid for conventional grapes to 42% for strawberries among fresh fruits and from 15% above prices paid for conventional carrots and tomatoes to 60% for potatoes. Furthermore, prices paid for fresh produce are found to vary by other product attributes, market factors, and household characteristics.

**Key words:** fresh fruits and vegetables, hedonic price, organic produce, organic premium, product attributes, Nielsen Homescan

## Introduction

The US market for organic foods has grown rapidly in the past decade as they have become increasingly affordable and available in mainstream grocery stores. In 2000, conventional supermarkets for the first time sold more organic food than any other venue[1]. Growth in the US organic industry has been fairly steady, averaging between 15 and 21% per year since 1997[2]. Retail sales of organic foods increased from $3.6 billion in 1997 to $13.8 billion in 2005, representing 2.5% of total US food sales. Sales of organic foods are estimated to rise to $23.8 billion by 2010[3]. Among the organic food categories, fruits and vegetables by far comprised the largest retail sales ($5.4 billion in 2005), having grown at an average annual rate of 21% during 1997–2003[4].

Organic foods, once considered a niche product sold primarily in specialty shops, are gaining wider acceptance among consumers. According to the 2005 Whole Foods Market[5] Organic Trend Tracker, 65% of Americans have tried organic foods and beverages, compared to 54% in both 2003 and 2004. An estimated 46% of total organic food sales are now handled by the mass-market channel, which includes supermarkets, grocery stores, mass merchandisers, and club stores[2].

Organic products are credence goods—consumers do not know whether a product is organic unless they are told[6]. The US Department of Agriculture (USDA) standards for organic foods, implemented in October 2002, aim at boosting consumer confidence in the organic label and, hence, facilitating further growth in the organic food industry. Consumer preference for organic food based on perceived desirable attributes and characteristics has been widely documented. Yiridoe et al.[7] provided a comprehensive review of literature on consumer perceptions and preference toward organic foods. Organic food was commonly perceived as a healthy and environmentally friendly option. Based on telephone interviews conducted in the United Kingdom, Tregear et al.[8] reported that 45% of respondents claimed to purchase organic produce because of concern for their own health while only 9% claimed to purchase for environmental concern. Previous studies have demonstrated that the consumer's level of income, age, gender (female), and the presence of children are the primary factors found in organic food purchase[9–12].

The contingent valuation approach has traditionally been employed to examine how high a price premium consumers are willing to pay for organic products and how socio-economic and demographic factors affect their willingness to pay. The findings from the extant literature tend to confirm that organic food products command a price premium[11,13–16]. However, the reported organic price premiums that consumers are willing to pay differ substantially among various studies. Goldman and Clancy[13]

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found, in general, that a third of respondents in New York were willing to pay a 100% price premium for organic foods. Thompson and Kidwell[11] reported that price premiums for organic produce ranged from 40 to 175% of their conventional counterparts, while O'Donovan and McCarthy[16] demonstrated that about 70% of Irish consumers were not willing to pay more than a 10% price premium for organic meat. Interestingly, Chang and Zepeda[17] observed that most participants in their study agreed that an organic price premium over conventionally produced foods is justified, but most of them did not know how much. They suggested that aside from the main problem of availability, price is a key obstacle preventing non-organic consumers from trying organic goods. In fact, a survey by Walnut Acres[18] reported that 68% of consumers cited high prices as the main reason they did not buy organic foods. Chang and Zepeda[17] suggest that increasing consumer awareness of organic farming and certification may be the most effective way of moving organic foods into the mainstream.

Empirical analyses of the US demand for organic produce have been limited and have focused mainly on how socio-economic and demographic factors affect willingness to pay for organic foods. There is little systematic study based on actual purchases of organic foods using national data. The objective of the study was to use the 2005 Nielsen[19] Homescan data to examine the effects of product attributes, market factors, and consumer characteristics on the price of fresh produce. The study focused on price premiums associated with the organic attribute of fresh fruits and vegetables purchased at retail outlets.

## Data

The Nielsen[19] Homescan panel consists of representative US households that provide food purchase data for at-home consumption. In 2005, the panel included more than 8500 households, which reported their purchases of foods that were sold as random weight or with the Uniform Product Code (UPC) at retail outlets. For UPC-coded (or packaged) food products, organic produce can be identified by the presence of the USDA organic seal or with organic-claim codes created by Nielsen[19]. For random-weight items, Nielsen[19] uses a coding system, which identifies organic produce. Homescan panelists do not report the unit prices for each food item; they report the total expenditure and the quantity of each food item purchased. In addition, the Homescan data include product characteristics and promotion information, as well as detailed socio-demographic information of each household.

For the purpose of this study, household purchase records of fresh produce, in general reported weekly, were aggregated into quarterly data. Before seasonal aggregation, purchase records were sorted and identified with the circumstance under which fresh produce were purchased. Specifically, each purchase can be identified by such as presence of UPC (packaged or not), type (organic or not), store (discount store or not), and sale (on sale or not). Prices for organic and conventional produce were derived as unit values—the ratio of the reported expenditures to the reported quantities for each purchase record, net of any promotional and sale discounts. To avoid potential problems that may be caused by inadvertent reporting errors, the derived unit prices for organic and conventional produce that were greater than the sample mean plus three standard deviations were considered as outliers and hence were excluded from the sample data.

Table 1 shows the average unit prices computed from Homescan panelists purchase records for organic and conventional fresh produce in 2005. As shown in Table 1, prices paid for fresh produce vary over a wide range, and the percentages of organic premiums over their conventional counterparts also vary greatly. Based on the sample information, organic premiums vary from about $\$0.16\,lb^{-1}$ (bananas) to $\$0.71\,lb^{-1}$ (strawberries) for fruits and from around $\$0.15\,lb^{-1}$ (onions) to about $\$0.52\,lb^{-1}$ (peppers) for vegetables. However, bananas and potatoes were found to command the highest relative price premiums among the fruits and vegetables, respectively. The percentages of organic premiums relative to conventional prices are 36% for bananas and 82% for potatoes.

It is of interest to note that, in general, when the percentages of organic price premiums are at their highest, the ratios of organic purchase relative to conventional purchases, organic penetration, are at their lowest. For example, Table 1 shows that potatoes command the highest organic price premiums (81.53%) but also have the lowest organic penetration (0.53%). Likewise, carrots have the lowest reported organic premiums (14.59%), while exhibiting the highest organic penetration (5.03%) in terms of the quantity of organic produce purchased relative to conventional produce. Similarly, the inverse relationship between organic penetration and organic premiums is also evident and observed in the panelists' purchasing behavior of oranges, which has the lowest organic price premium and the highest organic penetration among fresh fruits. Apple, banana, strawberry and pepper also show relative high price premiums being associated with relative low organic penetration. Tomatoes provide another example from the sample data showing high organic penetration that is related to low price premium. However, some exceptions are noted in Table 1 as in the cases of grape and onion, which show a relatively low price premium and low percentages of organic purchase relative to conventional produce.

## Hedonic Model

Recognizing some of the shortcomings and limitations of the neoclassical demand model, Lancaster[20] developed an alternative theory of consumer demand suggesting that it is the properties or characteristics of goods from which utility is derived. According to Lancaster[20], consumption is an activity in which goods and services, singly or in

**Table 1.** Summary of sample statistics for selected fresh produce, 2005.

| Commodity | Mean price[1] | | | Price range[1] | Organic | |
|---|---|---|---|---|---|---|
| | Organic | Conventional | Total | | Premium[2] | Penetration[3] |
| Fruits | ---------- Dollars per pound---------- | | | | ---------- Percent---------- | |
| Apple | 1.35 | 1.01 | 1.02 | 0.31–3.24 | 34.33 | 2.15 |
| | (0.54)[4] | (0.34) | (0.36) | | | |
| Banana | 0.62 | 0.45 | 0.46 | 0.20–2.46 | 36.03 | 2.37 |
| | (0.29) | (0.13) | (0.15) | | | |
| Grape | 1.81 | 1.48 | 1.48 | 0.57–4.98 | 22.48 | 1.46 |
| | (0.85) | (0.56) | (0.57) | | | |
| Orange | 1.07 | 0.90 | 0.90 | 0.18–4.13 | 19.12 | 3.63 |
| | (0.60) | (0.33) | (0.34) | | | |
| Strawberry | 2.78 | 2.08 | 2.09 | 0.76–7.98 | 34.08 | 1.86 |
| | (1.64) | (0.80) | (0.83) | | | |
| Vegetables | | | | | | |
| Carrot | 1.26 | 1.10 | 1.11 | 0.30–5.69 | 14.59 | 5.03 |
| | (0.65) | (0.51) | (0.52) | | | |
| Onion | 0.96 | 0.81 | 0.81 | 0.20–5.18 | 18.47 | 1.82 |
| | (0.45) | (0.47) | (0.47) | | | |
| Pepper | 1.98 | 1.47 | 1.48 | 0.34–7.00 | 35.35 | 2.27 |
| | (1.38) | (0.79) | (0.82) | | | |
| Potato | 0.92 | 0.51 | 0.51 | 0.10–4.37 | 81.53 | 0.53 |
| | (0.59) | (0.30) | (0.31) | | | |
| Tomato | 2.21 | 1.86 | 1.87 | 0.49–5.29 | 18.80 | 3.63 |
| | (1.10) | (0.88) | (0.89) | | | |

[1] All prices ($\$\,lb^{-1}$) were computed as a unit price paid by dividing total expenditure, net of any promotional and sale discounts, by the total quantity purchased.
[2] The organic premium is computed as the organic price premium divided by the conventional average price.
[3] The organic penetration represents the ratio of the quantity of organic produce purchased relative to the purchase of conventional produce.
[4] The numbers in parentheses are standard deviations.

combination, are inputs and in which the output is a collection of characteristics. Lancaster's[20] theory of the demand for characteristics plays a crucial role and lays the necessary conceptual framework in the development of modern hedonic demand literature.

Expanding on the idea that consumers purchase goods because of the utilities derived from the characteristics or attributes that the goods possess, economists have applied Lancaster's[20] theory to agricultural products and developed hedonic approaches for exploring price–quality relationships to estimate the implicit values of product characteristics[21–23]. Hedonic modeling efforts rely on the fact that consumers and producers recognize these product attributes in approximately the same ways, and that the choices each group makes lead to an equilibrium condition that neither the consumers nor the suppliers have any incentive to change.

The underlying assumption of a hedonic model is that products can be distinguished simply and uniquely by their characteristics. Thus, demand for various desired characteristics can be derived from consumer willingness to pay for a product. As a result, marginal or implicit values can be estimated for each attribute at the observed purchase price, which is linked to the number of characteristics contained in the goods purchased. For empirical analysis, the hedonic model for the study can be expressed as

$$P_{it} = \alpha_0 + \alpha_1 \mathrm{ORG}_{it} + \sum_{r=1} \gamma_r \mathrm{MKT}_{rit} + \sum_{s=1} \delta_s \mathrm{SOC}_{sit} + e_{it},$$

where $P_{it}$ is the price of the produce paid by the $i$th household in time $t$; $\mathrm{ORG}_{it}$ represents the organic attribute of the produce; $\mathrm{MKT}_{it}$ represents a set of market factors and characteristics such as packaging, type of store, on-sale occasion, and season of purchase; $\mathrm{SOC}_{it}$ is a set of socio-demographic factors that characterize the household, and $e_{it}$ is the error term. The list of variables representing product attributes, market factors, and household characteristics is presented in Table 2.

The hedonic price model represents essentially a reduced-form equation reflecting both supply and demand influences. There is little theoretical guidance with respect to the appropriate functional form that can be applied *a priori* in the regression analysis. Previous studies have used various functional forms, including the linear function[14,24–26], the semi-log function[24,27,28], and the more flexible functional form of a Box–Cox transformation model[29,30]. Consequently, the choice of the functional form for the hedonic price equation remains an empirical issue.

**Table 2.** Variables included in the hedonic model.

| Variable | Definition |
|---|---|
| Dependent variable | |
| Price | Unit price of fresh produce purchased, dollars per pound |
| Product attributes | |
| Organic | = 1 if organic produce, = 0 otherwise |
| Random weight | = 1 if the produce is sold as random weight, = 0 UPC-coded or packaged |
| Market factors | |
| Discount store | = 1 if the produce is purchased from supercenters or club warehouses, = 0 otherwise |
| Sale | = 1 if the produce is on sale, = 0 otherwise |
| Season | = 1 if the produce is purchased in a season (Spring–Winter), = 0 otherwise |
| Region | = 1 if the household resides in a region (Northeast, Central, South, and West) of the US, = 0 otherwise |
| Urban | = 1 if the household resides in an urban area, = 0 otherwise |
| Household characteristics | |
| Married | = 1 if the marital status is married, = 0 otherwise |
| Female head worked | = 1 if the female head of the household is not employed for pay, = 0 otherwise |
| Income | The ratio of household income over the federal poverty level; where household income is the midpoint of the income class |
| Child | = 1 if a child is present, = 0 otherwise |
| <High school diploma | = 1 if the highest education of the male or female head is less than high school diploma, = 0 otherwise |
| high school diploma | = 1 if the highest education of the male or female head is graduated from high school = 0 otherwise |
| Some college | = 1 if the male or female head has attended some college, = 0 otherwise |
| College degree and beyond | = 1 if the male or female head has a college degree or a post college education, = 0 otherwise. |
| <40 years | = 1 if the male or female household head is less than 40 years old, = 0 otherwise |
| 40–64 years | = 1 if the male or female household head is between 40 and 64 years old, = 0 otherwise |
| 65 years or older | = 1 if the male of female household head is at least 65 years old, = 0 otherwise |
| Race | = 1 if the household head is a particular race/ethnicity (White, Black, Hispanic, Oriental, and others), = 0 otherwise |

In the study, we chose the linear form for ease in result interpretation.

Given the nature of Homescan data that may contain multiple observations from the same household, the error terms are likely to be cluster-correlated and not independently distributed. Thus, the covariance estimates obtained from applying the standard ordinary least square estimation are likely to be biased, which would yield inappropriate standard errors and misleading tests of statistical significance[31]. The error terms in the hedonic price equation were assumed to be cluster-correlated, and we used the Stata[32] program, which performs the regression procedure via the weighted least squares for survey data, to estimate the hedonic equations.

## Empirical Results

In this study, we estimated the linear hedonic models for ten selected fresh produce. The five fruits (apple, banana, grape, orange and strawberry) and five vegetables (carrot, onion, pepper, potato and tomato) were selected for the analysis because they are the most popular and valuable produce purchased by Nielsen[19] Homescan panelists in terms of purchase frequency and sale values. The regression results for fresh fruits and vegetables are presented in Tables 3 and 4, respectively. The sample sizes vary by produce, depending on the purchase frequency. The goodness-of-fit measure, $R^2$, varies from 0.140 (grape) to 0.271 (banana) for fruits and from 0.062 (onion) to 0.349 (tomato) for vegetables. The relatively low $R^2$s reported in Tables 3 and 4 do not indicate poor model fit, and they are to be expected because cross-sectional data are used. Overall, the regression results appear reasonable and satisfactory because most of the estimated coefficients are statistically significantly different from zero with expected signs.

As shown in Tables 3 and 4, estimated price premiums for all ten fruits and vegetables were found to be statistically significantly different from zero at the 1% probability level. Organic price premiums for fruits were found to vary greatly, ranging from a low of 13 cents per pound for bananas, to a medium of 30 cents per pound for grapes and to a high of 86 cents per pound for strawberries. Among the five vegetables with the largest sale values in 2005, the organic price premiums were estimated to range from a low of 13 cents per pound for onions, to a medium of 28 and 31 cents per pound for tomatoes and potatoes, and

**Table 3.** Estimated regression model results for fresh fruits, 2005.

| Variable | Apple | Banana | Grape | Orange | Strawberry |
|---|---|---|---|---|---|
| Constant | 0.873 | 0.297 | 1.810 | 1.123 | 2.758 |
| Organic | 0.283*** | 0.129*** | 0.295*** | 0.188*** | 0.864*** |
| Random weight | 0.275*** | 0.160*** | −0.098*** | −0.221*** | −0.742*** |
| Discount store | −0.065*** | −0.042*** | −0.137*** | −0.084*** | −0.337*** |
| Sales | −0.203*** | −0.090*** | −0.333*** | −0.144*** | −0.124*** |
| Spring | −0.037*** | 0.002 | −0.041*** | −0.051*** | −0.194*** |
| Summer | −0.035*** | −0.003** | −0.024** | −0.071*** | −0.507*** |
| Fall | 0.025*** | −0.008*** | −0.163*** | 0.167*** | −0.280*** |
| Northeast | −0.024*** | 0.042*** | 0.009 | 0.000 | 0.047* |
| Central | −0.084*** | 0.000 | −0.117*** | −0.018* | −0.230*** |
| West | −0.066*** | 0.086*** | −0.008 | 0.001 | −0.261*** |
| Urban | 0.015* | 0.009* | −0.028 | 0.014 | −0.063*** |
| Married | −0.012 | −0.012*** | −0.031* | −0.008 | 0.127 |
| Female head worked | −0.022*** | −0.002 | −0.041*** | −0.004 | −0.034** |
| Child | 0.010 | −0.001 | 0.031* | 0.008 | 0.022 |
| Income | 0.020*** | 0.005*** | 0.024*** | 0.011*** | 0.024*** |
| Black | −0.043*** | 0.011*** | −0.019 | −0.012 | −0.030 |
| Hispanic | −0.066*** | −0.015*** | −0.095*** | −0.014 | −0.147*** |
| Oriental | −0.094*** | −0.021*** | −0.132*** | −0.087*** | −0.192*** |
| Others | 0.008 | 0.021** | 0.071 | 0.050* | −0.020 |
| Age < 40 | 0.052*** | 0.022*** | 0.080*** | 0.043*** | 0.055** |
| Age 65 and older | −0.038*** | −0.016*** | −0.034*** | −0.031*** | −0.055*** |
| Less than high school | −0.035 | 0.015 | 0.006 | 0.007 | −0.014 |
| High school | −0.002 | −0.004 | −0.016 | −0.009 | −0.027 |
| Some college | −0.007 | −0.002 | −0.010 | −0.007 | −0.033* |
| *R*-squared | 0.266 | 0.271 | 0.140 | 0.172 | 0.238 |
| Sample size | 27,220 | 36,605 | 20,161 | 12,473 | 15,928 |

Note: ***, **, and * indicate the estimated coefficients are significantly different from zero at least at the 1, 5, and 10% significance level, respectively. The significance level of the constant term is not indicated.

to a high of 50 cents per pound for peppers. Except for peppers and strawberries, we found the organic price premiums to converge in the 13–21 cents-per-pound range among the fresh produce studied. In general, fresh produce with greater variation in seasonal availability (e.g., strawberries) was found to command a higher organic premium than produce that is available year round (e.g., bananas and onions).

Previous studies using a contingent valuation approach typically expressed organic price premiums as a percentage over the prices of conventional produce instead of absolute dollars and cents, because it is easier for respondents to report their willingness to pay for organic produce in relative terms. Moreover, in many cases the actual prices paid for organic foods were not available. In this study, we estimated the organic price premiums in dollars and cents and we also computed the estimated premiums relative to the prices of conventional produce so that we can compare our estimates to those reported in the literature. In terms of percentages, the ratio of the estimated organic premiums to average prices of conventional produce varies from less than 20% for grapes to over 42% for strawberries.

For vegetables, the percentages of organic premiums to conventional prices vary from about 15% for tomatoes and carrots to as high as 60% for potatoes. The high price premiums associated with organic potatoes is consistent with previous findings. According to a case study conducted by Wyman and Diercks[33], growers needed price premiums that ranged from 24 to 228% over conventional potatoes just to break even depending on the variety of potatoes. They suggest this is due to the higher costs and lower yields of organic potato production relative to other organic produce. For ease of comparison, the estimated price premiums for organic produce both in terms of dollars and cents and in percentages are shown in Figure 1.

As expected, the results show that fresh produce prices are significantly affected by various product attributes, market conditions, and consumer characteristics. The estimated coefficients for random-weight produce (price premiums or discounts of random-weight produce versus packaged produce) were found to be highly significant among all fruits and vegetables. However, the signs on the estimated coefficients are mixed, as they can be either positive or negative. A positive coefficient signals that the random-weight produce (e.g., apples) was sold at a higher price than its packaged counterpart. Packaged apples are sold at a lower price than random-weight apples because of quantity discount. For the same reason packaged bananas, onions, and potatoes were sold at a discount price compared

**Table 4.** Estimated regression model results for fresh vegetables, 2005.

| Variable | Carrot | Onion | Pepper | Potato | Tomato |
|---|---|---|---|---|---|
| Constant | 1.246 | 0.759 | 2.570 | 0.477 | 2.725 |
| Organic | 0.168*** | 0.134*** | 0.504*** | 0.306*** | 0.282*** |
| Random weight | −0.417*** | 0.098*** | −1.182*** | 0.252*** | −1.006*** |
| Discount store | −0.133*** | 0.083*** | −0.311*** | −0.070*** | −0.376*** |
| Sales | −0.005 | −0.120*** | −0.281*** | −0.121*** | −0.302*** |
| Spring | −0.010 | −0.040*** | −0.142*** | −0.034*** | −0.142*** |
| Summer | 0.021*** | −0.005 | −0.089*** | −0.026*** | −0.107*** |
| Fall | 0.031*** | 0.018*** | −0.209*** | −0.003 | −0.218*** |
| Northeast | −0.095*** | −0.001 | 0.203*** | 0.004 | 0.022 |
| Central | −0.137*** | −0.064*** | −0.084** | −0.087*** | −0.111*** |
| West | −0.112*** | −0.117*** | 0.013 | −0.078*** | 0.034 |
| Urban | −0.004 | 0.041*** | 0.115*** | 0.027*** | 0.018 |
| Married | −0.038*** | −0.030*** | −0.042** | −0.030*** | −0.033** |
| Female head worked | −0.049*** | −0.020** | −0.047*** | −0.007 | −0.048*** |
| Child | 0.020 | 0.021** | 0.063** | −0.008 | 0.046*** |
| Income | 0.020*** | 0.017*** | 0.049*** | 0.017*** | 0.044*** |
| Black | −0.013 | −0.080*** | −0.081*** | −0.031*** | −0.135*** |
| Hispanic | −0.060*** | −0.082*** | −0.149*** | −0.041*** | −0.179*** |
| Oriental | −0.167*** | −0.136*** | −0.183*** | −0.059*** | −0.192*** |
| Others | −0.091*** | −0.103*** | 0.042 | 0.013 | −0.025 |
| Age < 40 | 0.072*** | 0.039*** | 0.178*** | 0.025*** | 0.065*** |
| Age 65 and older | −0.077*** | −0.026*** | −0.051** | −0.018*** | −0.057*** |
| Less than high school | 0.060 | −0.034 | −0.033 | −0.057*** | −0.067 |
| High school | −0.017 | −0.034*** | −0.049* | −0.027*** | 0.014 |
| Some college | −0.012 | −0.018** | −0.048** | −0.014*** | −0.007 |
| *R*-squared | 0.151 | 0.062 | 0.198 | 0.297 | 0.349 |
| Sample size | 22,746 | 28,989 | 15,553 | 28,634 | 30,730 |

Note: ***, **, and * indicate the estimated coefficients are significantly different from zero at least at the 1, 5, and 10% significance level, respectively. The significance level of the constant term is not indicated.

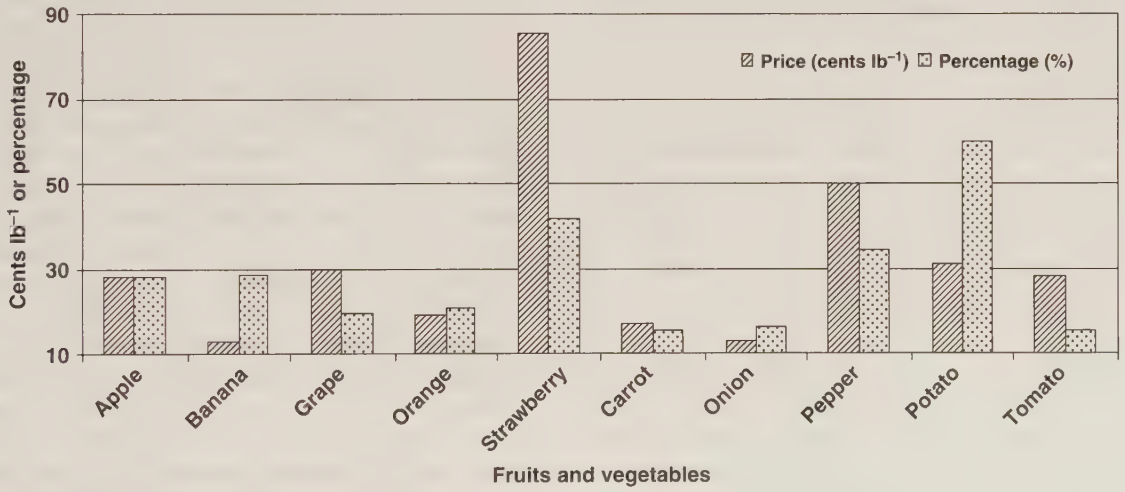


**Figure 1.** Organic price premiums: fresh produce, 2005. Source: Nielsen Homescan panel data, 2005.

to their random-weight counterparts. On the other hand, the random-weight tomatoes were priced lower than packaged tomatoes, this is because packaged tomatoes are usually of more consistent quality or less ordinary varieties (such as grape or on-vine tomatoes) than random-weight tomatoes. Random-weight grapes, oranges, strawberries, carrots, and peppers were found to be priced lower than their packaged counterparts as well. The price discount for random-weight produce is particularly noticeable for strawberries (74 cents per pound), peppers ($1.18) and tomatoes ($1.01).

As expected, fresh produce sold at discount stores were priced significantly lower, except for onions (Table 4). Significant price discounts at discount stores ranged from 7 cents per pound for apples and potatoes to a high of

34 cents for strawberries and 38 cents for tomatoes. It is surprising to see that onions sold at discount stores were priced significantly higher than onions sold elsewhere.

Not surprisingly, fresh produce were priced significantly lower when they were on sale than not on sale, except for carrots. Price discount on carrots when they were on sale was found to be statistically insignificant. When on sale, apples were sold for 20 cents less per pound than regular-priced apples (Table 3). Grapes and tomatoes were discounted the most when they were on sale, averaging 33 cents per pound for grapes and 30 cents for tomatoes.

Considerable seasonal price variations among fresh produce were evident from the estimated results. In general, produce prices were found to be significantly higher in the winter when the production and supply of fresh produce are limited, compared to other quarters. This is true for grapes, strawberries, peppers, potatoes, and tomatoes. For apples and oranges, their prices appear to peak in the fall season when the harvest of new crops enters the fresh produce market. The results also indicate that there are some significant regional variations on produce prices. Specifically, we found households that reside in the south paid a significantly higher price for apples and carrots than those residing in other regions of the United States. On the other hand, households in the northeastern and western regions paid a significantly higher price for bananas, about 4 and 9 cents per pound, respectively, than the southerners. Households in the urban areas, in general, paid significantly higher prices for fresh vegetables such as onions, peppers and potatoes than those living in the rural areas.

With respect to household characteristics, we found that married households and households with an employed female head paid a lower price for fresh produce than their counterparts. In particular, married households paid a significantly lower price for fresh vegetables at 3–4 cents per pound less than not-married households. Significantly higher prices were paid for grapes, onions, peppers and tomatoes when there was a child present in the household.

Further as expected, households with higher income also paid a higher price for produce than less-well-off households. Higher-income households are more likely to purchase higher priced or higher quality food products or shop at retail outlets that offer more customer service and/or are located in high rent areas. Our finding is consistent with those of Thompson and Kidwell[11] who found that higher household income increases the probability that a household will choose to shop at specialty grocery stores, which tend to maintain higher prices on average, not only for fresh produce but also for other products. The results also show that prices paid for fresh produce varied significantly among households of different race and ethnicity. This finding suggests that Hispanic and oriental households consistently paid a significantly lower price for fresh produce, except for oranges, than white households. Black households were also found to pay significantly lower prices, less than white households, for some fruits (apples and bananas) and most vegetables (except for carrots).

The age of the household head (represented in three categories) is mostly highly significant, and the coefficient can be either positive or negative. The estimated coefficients are positive when the age of the household head is below 40 years old and negative when the household head is older than 65 years of age. This implies that younger consumers bought fresh produce at a higher price than their older counterparts. Govindasamy and Italia[12] reported that younger respondents were more willing to pay a premium for organic produce than were older respondents. With the exception of peppers purchased by consumers under the age of 40, the estimated coefficients vary from 2 to 8 cents per pound in prices paid.

In this study, we found almost no significant associations between educational attainment and prices paid for fresh fruits (Table 3). However, some evidence suggests that household heads with college or postgraduate degrees were paying a higher price on onions, peppers and potatoes than their counterparts. Previous studies have reported mixed findings concerning the relationship between educational attainment and organic purchase behavior. Our study appears in agreement with the findings of Roddy et al.[10] suggesting that 'organic purists' are more likely to be highly educated and in a high-income category. Govindasamy and Italia[12], on the other hand, reported that consumers' willingness to pay a premium for organic produce decreases as the level of education increases.

## Summary and Conclusions

Organic demand and markets have received considerable research interest. Many studies have examined how high a price premium consumers are willing to pay for organic products and how socio-economic and -demographic factors affect their willingness to pay, using a contingent valuation approach. These studies have measured attitudes toward the purchase of organic produce rather than actual purchases. To our knowledge, empirical analyses of demand for organic produce have been limited and there is no systematic study, using national data, of variations in price premiums across produce type, season, market area, and consumer characteristics.

This study estimated a hedonic price model based on data from the 2005 Nielsen[19] Homescan panel, a nationally representative panel, to assess consumer valuation of various attributes of fresh produce, including organic production. The hedonic methodology proved useful as a tool for analyzing price variation in fresh produce and as a mechanism for examining consumer preferences for particular product attributes. Overall, the signs and magnitudes of the organic price premiums obtained in this study appear to be reasonable and plausible.

The results show significant organic price premiums for all fresh produce examined in this study, varying from 15% above the average conventional price for carrots and tomatoes to just above 60% for potatoes. In terms of absolute price level, we estimated that the organic price

premiums vary from 13 cents per pound for bananas and onions to 86 cents per pound for strawberries. Our results reflect a range of price premiums for organic produce that is noticeably lower than previous studies, such as that of Thompson and Kidwell[11]. This could be attributed to the reported steady growth of the US organic industry since 1997 and the increase retail sales of organic foods[2]. Furthermore, the estimated high premium for potatoes appears reasonable and consistent with previous study, as Wyman and Diercks[33] showed that a high markup is needed for organic potato production to become profitable.

These results provide interesting insights to the general public as well as the organic industry concerning the prices that consumers are paying in the marketplace for organically produced fresh produce. As suggested by previous studies[11,16,17], willingness to pay for organic foods varies greatly among consumer groups. Aside from availability, higher prices for organic produce could be a key deterrent that discourages nonorganic consumers from purchasing organic foods. By increasing the consumer awareness of organic foods and the positive attributes associated with organic foods, price could become a lesser consideration with nonorganic consumers. The organic price premiums reported in this study appear quite large for some produce and additional research of these high price premiums is recommended.

Particular attention and further study may be needed for the organic pepper industry. Because of their hardiness and ease of propagation, peppers are crops that lend themselves to small-scale and part-time farming operations and are grown in 48 states[34,35]. In a highly diverse production market such as the pepper market, substantial growth potential may exist in niche markets, particularly the organic market. In view of increasing interest of and demand for locally grown foods in recent years and the fact that organic peppers command a higher organic price premium, both in terms of absolute and relative price premiums, than other fresh vegetables considered in this study, we would expect further expansion of the local organic pepper industry.

The Homescan data are available for several years before and after the implementation of the USDA Organic Standards; consequently, the data are suitable for monitoring the organic food market in future studies. Furthermore, our analysis is limited to the at-home market. An important food-related lifestyle change of the past two decades is the increase in consumption of food prepared away from home. In 1970, food away from home accounted for 26% of total US food spending[36]. The share rose to 42% in 2006. The rising popularity in eating out could potentially present an additional growth of demand to the organic produce industry. However, there is little to no information available about consumer demand for organic foods when they eat out. Further research to study the demand for organic produce in the food away from home markets is needed to provide a more complete picture of the overall demand for organic produce.

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# Economics of organic and conventional hazelnut production in the Terme district of Samsun, Turkey

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## Abstract

Understanding the economics of organic agriculture is crucial to support of organic production by policy-makers and to facilitate producers converting their lands to organic production. The aim of this research was to compare organic and conventional hazelnut producers, in terms of their socio-economic characteristics, production systems and economic performance. The main data were gathered with surveys of 64 randomly selected conventional hazelnut producers and all the organic hazelnut producers (39) living in villages of the Terme district of Samsun, Turkey in 2005. Results revealed that, compared to conventional hazelnut producers, organic hazelnut producers were more educated, had larger hazelnut areas and spent more time on agricultural activities. The current research also used cluster analysis to define relatively similar farmers from both production systems and to compare variables. Organic producers needed more labor, especially hired workers, and used more lime, organic fertilizer and insect traps, while conventional producers used more synthetic inputs. Organic producers had lower costs of production and had higher income. It is recommended that the organic producers be supported financially, and assisted by research and extension services to produce and use their own inputs, rather than purchasing from outside. They should also be encouraged to establish associations to increase their marketing efficiency.

**Key words:** economics, organic agriculture, cluster analysis, hazelnut, Turkey

## Introduction

Although organic agriculture has a long history, the market for organic products has only recently been developed worldwide, due to increasing consumer demand for healthy foods. In addition, increased awareness of environmental conservation among both consumers and producers has accelerated the development of organic agriculture[1,2]. It is currently practiced on about 31 million ha of land on 635,000 organic farms in about 120 countries worldwide[3]. The latest survey revealed that there are 6,563,352 ha of land in 165,330 organic farms in the European Union's (EU) 27 member states, which corresponds to about 3.6% of the total agricultural land[4]. Worldwide, organic food and drink sales are worth about 33 billion US$[3]. Although the organic food market is currently only 1–4% of total food sales globally, it is growing rapidly, with the demand mainly concentrated in North America and Europe[5].

Organic agricultural activities were introduced to Turkey by European companies in the mid-1980s. At the beginning, these companies focused on classical Turkish agricultural export products such as dried figs, sultanas, apricots and hazelnuts. In parallel with the increase in demand from European countries, organic products in Turkey were diversified and production areas increased[6]. Organic agriculture developed rapidly between 1990 and 2006. The number of organic products increased by over 26-fold (from 8 to 210), the number of organic producers increased over 45-fold (from 313 to 14,256) and the area under organic management increased about 186-fold (from 1037 to 192,789 ha, including lands being converted) over the same period[7]. Although only 0.8% of total agricultural land is currently organic, this share is expected to reach 3% by 2013 and 8% by 2020[8]. Turkey is now one of the most important organic product suppliers to European markets. Most of the domestic organic production (about 80%) is exported and it represented about 30 million US$ in 2006[7].

Turkey is responsible for more than 75% of global hazelnut production and dominates the international

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market. Hazelnuts, one of the most important organic export products of Turkey, are mainly grown in the Black Sea region[6]. Organic hazelnut exports were valued at about 30% of the total organic exports of Turkey in 2006; there were about 550 organic producers who produced 7159 tons of hazelnuts on 4100 ha[7].

A literature review revealed many studies of the economics of organic production worldwide[9–14]. However, only a few studies on the economics of organic hazelnut production were found from Turkey[6,15,16] and Italy[17]. These studies compared conventional and organic hazelnut systems. However, they failed to consider factors such as location, soil structure, farm size, production system and socio-economic background of operators.

Methodological issues have long been discussed by researchers in comparing organic and conventional production systems[18–22]. When researching and comparing those systems, the factors mentioned above should be considered, and relatively similar farms and farmers from the same region should be selected by an appropriate sampling method. For that reason, cluster analysis was used in this research, to define and compare relatively similar organic and conventional farms and farmers.

The comparison of organic and conventional producers in terms of their socio-economic characteristics can show the relative economic performance of organic agriculture, help to support organic agriculture through modified policies and develop markets for organic products. Specifically, knowing the characteristics of good organic producers facilitates the defining of leader farmers[23] in rural areas. This can help diffuse organic agriculture among producers through directing limited sources (i.e. time, finance and staff) to these pioneer producers, which will in turn be an example for potential organic producers. Therefore, the aims of this research were to compare the (i) socio-economic characteristics, (ii) production systems and (iii) economic performance of organic and conventional hazelnut producers in Turkey.

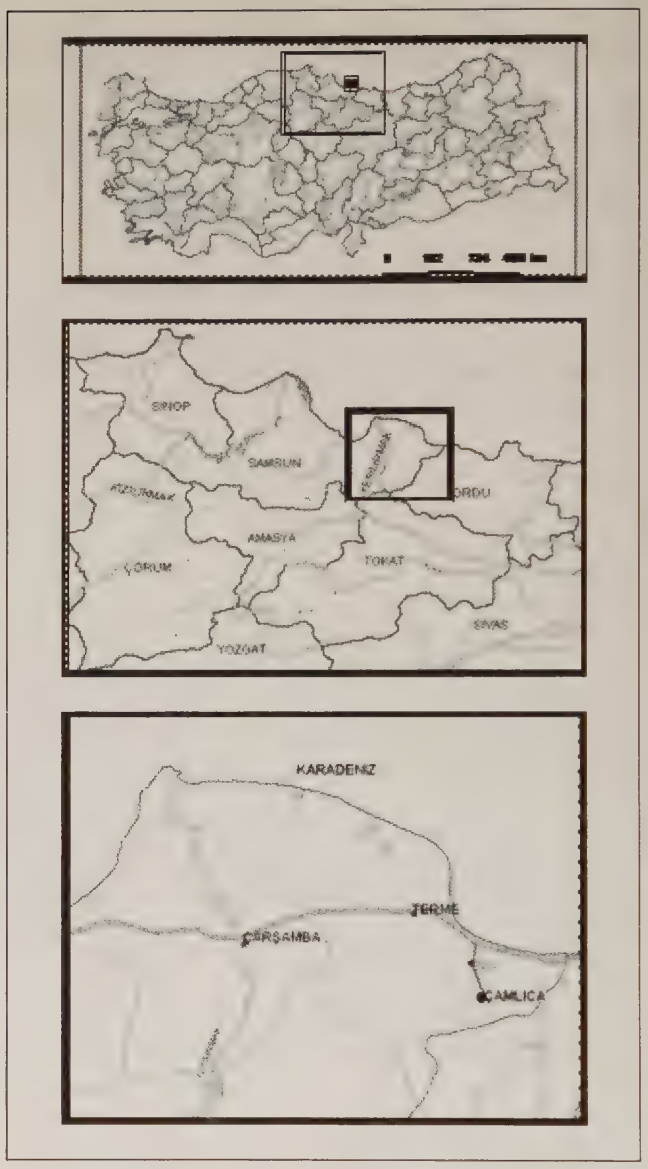


**Figure 1.** The maps of Terme district of Samsun, Turkey.

## Materials and Methods

This study used a structured questionnaire to capture information. The main data of the research were collected from 64 randomly selected, conventional hazelnut producers and all the organic hazelnut producers (39) in the Terme district of Samsun province, Turkey (Fig. 1), during the production period 2004–2005. The survey targeted answers to its questions to be 95% accurate, with a 10% margin of error. Regarding validity and reliability of the survey, the authors conducted pilot interviews with five organic and five conventional producers to test the survey before the main fieldwork. Reliability was assessed using the test–retest method in which the survey was administered to the same group at two different times. Alpha[24] was used as an index of internal reliability or consistency for a set of questions, and an alpha of 0.80 or higher was considered to indicate an acceptable level of internal reliability.

The database of the research was extended with field observations, group discussions and interviews with selected leader farmers and the staff of public organizations. However, these data were mainly used to support and interpret the main survey data. The records of the Provincial Agricultural Directorates of the Ministry of Agriculture and Rural Affairs (MARA), the reports of public organizations and previous research results were also used in the research. Multiple data collection techniques were used to increase the validity and reliability of the research through triangulation.

In addition, this research is part of a longitudinal study in that the results were compared with previous research[6] conducted in the same area in 1997. The results of this study were also compared with previous studies on organic hazelnut production in other parts of Turkey[15,16] and Italy[17].

**Table 1.** Some characteristics of organic and conventional hazelnut producers selected on the results of cluster analysis.

| | Organic ($n = 19$) | | Conventional ($n = 17$) | |
|---|---|---|---|---|
| **Variables** | **Mean** | **Standard deviation** | **Mean** | **Standard deviation** |
| Age (years) | 54.1 | 15.2 | 57.1 | 15.2 |
| Formal education (years) | 6.2 | 3.4 | 4.8 | 3.4 |
| Farming experience (years) | 35.0 | 18.4 | 39.2 | 13.7 |
| Cultivated land (ha) | 4.9 | 1.5 | 5.3 | 2.0 |
| Hazelnut area (ha) | 4.6 | 1.3 | 4.5 | 1.5 |

**Table 2.** Personal characteristics of organic and conventional producers.

| | Organic ($n = 39$) | | Conventional ($n = 64$) | |
|---|---|---|---|---|
| **Personal characteristics (number of years)** | **Mean** | **Standard deviation** | **Mean** | **Standard deviation** |
| Age | 51.8 | 14.4 | 54.0 | 14.5 |
| Formal education* | 7.5 | 3.6 | 5.0 | 3.2 |
| Conventional experience* | 25.9 | 18.5 | 34.7 | 14.1 |
| Organic experience* | 9.0 | 7.8 | 0.4 | 1.3 |

* $P < 0.01$.

The variables in this study can be divided into three broad groups: personal characteristics (age, education level and experience); farm characteristics (income sources, time allowance, own land, cultivated land, hazelnut area, capital, credit use, farm income and off-farm income) and hazelnut production characteristics (manure use, organic fertilizer use, lime use, cost of pest traps, cost of pesticides, nitrogen use, phosphorus use, labor use, hazelnut yield, hazelnut price, hazelnut cost per kg and gross margin for hazelnut).

When comparing personal characteristics and some farm characteristics, such as income sources, own land, cultivated land and hazelnut area, the authors included all organic hazelnut farms and randomly selected conventional farms for the analysis.

Since the production system among sample conventional and organic farms varied considerably, cluster analysis was used to define similar farms and farmers from both production systems, in terms of hazelnut production area, soil conditions, production techniques, similar and close locations, socio-economic status and management conditions, when comparing monetary variables.

Cluster analysis is one of the multivariate analytical techniques which group respondents on the basis of characteristics they possess. It classifies respondents so that each respondent is very similar to others in the cluster, with respect to some predetermined selection criterion[25]. Cluster analysis was applied to the farm data such as the age, experience and education level of operators; farmland; and hazelnut area. The cluster analysis defined 19 organic and 17 conventional hazelnut farms with similar personal characteristics (age, education and farming experience) of growers, and similar size of hazelnut production areas, with the differences among them being statistically non-significant (Table 1). Based on the results of cluster analysis, hazelnut yields, labor and input uses, costs and incomes of conventional and organic hazelnut farms were compared.

The Student's *t*-test was used to test the hypothesis that means were equal, in terms of scale variables when comparing the two production systems. Statistical tests were performed with the Statistical Package for the Social Sciences (SPSS).

## Results and Discussion

### *Age, education and experience*

The age of a farmer is an important characteristic in explaining some aspects of decision-making and technology diffusion. The ways people behave, think and express their needs are closely related to age[26]. An older person's experience may be equated with knowledge and judgment. On the other hand, ageing may adversely affect the transfer of information and technology in rural societies through negatively influencing the understanding and acceptance of innovation. Farmers' age profiles are related to appropriate extension methods; for example, where educational standards are rising from low levels, literacy and numeracy may be mainly associated with the younger ages[6].

As can be seen from Table 2, both organic and conventional hazelnut producers were generally older and there was no statistical difference between them, although organic producers are expected to be young and innovative. This result confirms the results of similar research

**Table 3.** Income sources and time allowance for work activities.

| Income sources and time allowance (%) | Organic ($n = 39$) | | Conventional ($n = 64$) | |
|---|---|---|---|---|
| | Mean | Standard deviation | Mean | Standard deviation |
| Agricultural income/total income* | 80.1 | 20.9 | 71.2 | 27.4 |
| Non-agricultural income/total income* | 19.9 | 20.9 | 28.8 | 27.6 |
| Time for agricultural work** | 51.9 | 20.7 | 37.5 | 20.7 |
| Time for non-agricultural work** | 48.1 | 21.0 | 62.5 | 20.3 |

* $P < 0.05$ and ** $P < 0.01$.

conducted in the same area[6]. Due to the demographic structure of the region, older people generally stay in the villages, and relatively younger people go to towns and cities to find work.

This finding confirms the generalization of Rogers[27] who reviewed numerous studies of the relationship of age to innovativeness and found that in half of these studies, there was no particular relationship. However, several research studies conducted in different countries implied that organic producers were relatively younger, had urban backgrounds and were new entrants to agriculture[28,29]. Overall, it is concluded that age, as a discrete factor in this research, appears to have had little or no influence on the decision to produce organic hazelnuts.

Another characteristic, education, as a process of learning, is usually perceived to be synonymous with formally structured institutions such as schools. Formal education is an investment in farmers' development. However, it can usefully be followed by, and supported with, functional non-formal education such as extension programs and distance education[1,30].

In this research, the education level of organic hazelnut producers, who generally had secondary school education, was significantly ($P < 0.01$) higher than that of conventional hazelnut producers, who generally had primary school education (Table 2). A similar result was found in previous research in the same area[6]. These findings are also supported by several research studies conducted in different parts of the world that showed that organic farmers generally had higher levels of formal education[19,28,29].

Experience can be simply defined as knowledge or skill which is gained while doing a job[31]. The current knowledge and experiences of farmers influence their behavior at work[6]. Some previous studies have shown that most organic producers have had conventional farming experience[19,32–34]. As expected, the organic hazelnut producers had more organic production experience than conventional hazelnut producers ($P < 0.01$) (Table 2). Average organic production experience in the same research area was 4.5 years in 1997[6]. These two studies indicate that some of the producers have recently adopted organic agriculture, while others have ceased for various reasons. On the other hand, this result also implies that most of the organic producers in the research area have continued in organic agriculture.

### *Income and time allowance for agricultural and non-agricultural work*

One factor that emerged from this study is that hazelnut growers earned most of their income from agriculture. Although some farmers also have other jobs apart from farming, they generally spent most of their time on agriculture. However, factors such as low farm income, seasonal production, temporary unemployment, higher risks in agriculture and desire to increase income, create pressure for farmers to seek other occupations.

In this research, both groups of producers were asked to rate their sources of income and time allowance for agricultural and non-agricultural tasks. Table 3 shows that, compared to conventional hazelnut producers, organic producers spent more time on agricultural pursuits ($P < 0.01$). As expected, both groups of producers earned most of their income from agriculture. Interestingly, the share of non-agricultural income for conventional producers was higher than that of organic producers ($P < 0.05$), but overall they earned relatively lower income than the organic producers (Table 5). The fieldwork observations revealed that this mainly resulted from different types of work, in that most conventional producers generally worked in paid hourly labor off-farm, while relatively wealthier organic producers dealt with commerce. This supports previous research[6] that revealed that organic producers have higher social status, which was defined by Rogers[27] as a complex of factors, including income, level of lifestyle, possession of wealth and occupational prestige.

### *Land tenure*

Land tenure refers to the rights of people to the land which they control or cultivate; tenure is a social relationship between people and the land. It is also closely associated with other variables such as the size of agricultural holdings, the system of agriculture and the class system[27].

The status of land tenure in the two groups was similar (Table 4). The majority of the total cultivated land was owned by the producer alone. Another common type of land use was that producers were cultivating farms with their family members such as parents, adult sons or

**Table 4.** Land tenure of organic and conventional hazelnut producers.

| | Organic ($n = 39$) | | Conventional ($n = 64$) | |
|---|---|---|---|---|
| **Land tenure (ha)** | **Mean** | **Standard deviation** | **Mean** | **Standard deviation** |
| Own area* | 7.6 | 6.1 | 4.4 | 3.6 |
| Cultivated land* | 7.8 | 6.1 | 4.5 | 3.6 |
| Hazelnut area* | 6.3 | 3.6 | 4.0 | 3.2 |

* $P < 0.01$.

brothers. It was interesting that taking or giving land for sharecropping or leasing was not common among the respondents, although they are in some other areas of Turkey. These results confirmed previous research results in the same area[6].

The respondents were evidently not exposed to pressures for renting or sharing their land with people other than their relatives. The reason for this low level of land renting or sharing may have been due to owning a small area with several co-owners.

Only middle-aged and elderly people work on their land during the non-harvest period. On the other hand, younger people go to town to find a job, and some small land inheritors live and work in cities. Since hazelnut production does not require intensive input use and care, farming practices on their land are done by their relatives in the village or hired labor. Those people generally come to their land for the harvesting period which starts in late July. During harvesting, villages are crowded with local inhabitants, small landowners and labor hired for harvesting. At the end of August, hazelnut-producing villages in the Black Sea region are depopulated again, with only older people staying in the villages.

This study showed no real difference between organic and conventional producer respondents with regard to the allocation of land to different farm enterprises and product. As expected, most of the cultivated land was allocated to hazelnut production. This is a consequence of the very suitable soils, climate and topography of the area, coupled with hazelnuts being one of the most valuable cash crops in the region, and also relatively easy to grow. Apart from hazelnuts, farmers grow fruits and vegetables in small gardens near their homes.

As can be seen in Table 4, the hazelnut areas of organic producers were higher than those of conventional producers ($P < 0.01$). This finding confirms previous research in the same area[6]. This difference reflects the purposeful selection of producers by the organic contracting company, especially during the introduction of organic agriculture to the region. The company selected producers with relatively larger hazelnut areas from the same region and made contracts with them. This provided the company with access to a smaller number of producers who had larger farms, and hence it was easier to manage their operation and deal with producers. It meant that the company's project manager in the area could spend more time with a limited number of producers.

The average organic farm size in most countries is smaller than the conventional farm[19,29]. These organic farmers generally had urban backgrounds and were new entrants to organic agriculture. On the other hand, in Germany[35] and Switzerland[36], there were no differences in terms of farm size between organic and conventional producers. In fact, Dubgaard found that commercial organic producers had relatively larger areas[37].

### *Capital, credit and farm income*

The income of a producer is mainly influenced by current capital and credits taken from outside, both from banks and personal borrowings. On the other hand, the rate of credit use is one of the indicators that the farm is market oriented. The agricultural capital in Turkey is mainly composed of land capital. Depending on the credit conditions, including interest rates, due date and paper works, credit use in rural areas is generally very low[38–40].

The organic hazelnut producers used more (over 5-fold) credit per area than conventional producers ($P < 0.01$) (Table 5). The Turkish Agricultural Bank provides credit at low interest rates and with extended due date for organic producers. Similarly, the organic hazelnut producers used about 30% more working capital per area compared to the conventional producers. As a result of credit and capital used per hectare, the organic producers earned about 21% more farm income per unit of area than their conventional counterparts ($P < 0.01$) (Table 5).

Demiryurek also found that the farm income of organic hazelnut producers was more than that of conventional producers in the same area[6]. This was mainly due to a 12% premium on price available to the organic producers in 1997. In England, there were no agricultural income differences between similar organic and conventional farms[41]. The organic producers in Germany, Canada and Denmark obtained more agricultural income, while conventional producers received more income in Switzerland, Australia and the USA[10]. Padel reviewed studies from around the world and concluded that the economic performance of organic agriculture depends mainly on consumer demand, market availability and government support[29].

**Table 5.** Capital, credit and income of organic and conventional hazelnut producers.

| Capital, credit and income (US$ ha$^{-1}$) | Organic ($n = 19$) | | Conventional ($n = 17$) | |
|---|---|---|---|---|
| | Mean | Standard deviation | Mean | Standard deviation |
| Credit* | 543.6 | 630.5 | 99.7 | 224.3 |
| Working capital | 3104.2 | 2255.0 | 2394.7 | 1724.8 |
| Non-agricultural income | 1531.6 | 2079.2 | 762.9 | 1176.4 |
| Farm income* | 1544.4 | 1490.7 | 1276.4 | 834.3 |

* $P < 0.01$.

**Table 6.** Input use of organic and conventional hazelnut producers.

| Input use | Organic ($n = 19$) | | Conventional ($n = 17$) | |
|---|---|---|---|---|
| | Mean | Standard deviation | Mean | Standard deviation |
| Farm manure (kg ha$^{-1}$) | 3002.0 | 1050.7 | 2533.4 | 1644.6 |
| Organic fertilizer (kg ha$^{-1}$)* | 258.6 | 201.7 | – | – |
| Lime (kg ha$^{-1}$)* | 1145.2 | 412.2 | 263.6 | 463.6 |
| Cost of pest traps/pesticide (US$ ha$^{-1}$)* | 276.7 | 188.2 | 789.6 | 410.6 |
| Nitrogen (kg ha$^{-1}$)* | – | – | 236.1 | 108.6 |
| Phosphorus (kg ha$^{-1}$)* | – | – | 47.2 | 66.1 |

* $P < 0.01$.

## *Input use*

This section compared organic and conventional producers in terms of input use. The type of input use is one of the factors which differentiates organic production systems from their conventional counterparts[42,43].

The organic hazelnut producers used no synthetic fertilizers or pesticides. Indeed, the gardens, soils and products of organic producers were analyzed by the contracting company and the certification body during and after the production period. On the other hand, conventional hazelnut producers did use synthetic fertilizers and pesticides. Two kinds of fertilizers were commonly used, namely nitrogen (N) fertilizer as calcium ammonium nitrate and phosphate (P) fertilizer as triple superphosphate.

Table 6 shows that more nitrogen fertilizer was used than phosphate fertilizer. One reason for this was a difference in the frequency of use: N was used every year, while P was used once in three years due to its relatively longer retention than N in the soil. This result was confirmed by previous research[6].

Liming reduces soil acidity and increases the availability of certain plant nutrients in the soil. However, with high rainfall and inclined areas, as is the case in the Black Sea region, calcium is easily leached from the soil, and soils are generally acidic. Hence liming was required by both conventional and organic (allowed) hazelnut producers[6]. In particular, both the organic company representatives and public extension workers advised farmers to apply lime.

Although lime was used by both groups of producers, the organic hazelnut growers used more lime (1145.2 kg ha$^{-1}$) than the conventional producers (263.6 kg ha$^{-1}$) ($P < 0.01$) (Table 6). Demiryurek[6] also found a similar result in that more organic producers (85%) applied lime than conventional producers (33.3%). The main reason for this difference may be explained by unawareness of the need for lime application among conventional producers, and the lack of advisory support for them.

Manure is a source of plant nutrients and organic matter, especially for organic producers, and its application was also advised by the private and public advisors. However, most of the conventional hazelnut producers were also applying manure in addition to synthetic fertilizers. They were also aware of the advantages of manure in terms of improving the properties of the soil[6].

Although the organic hazelnut producers used more manure per unit of area than the conventional producers, there was no statistically significant difference between them. The main reason was that the organic producers used organic fertilizers, in addition to farm manure. Recently, organic fertilizer application has become popular among organic hazelnut producers due to its easy use. They were previously using poultry manure in addition to farm manure[6], but the use of poultry manure from conventional enterprises was banned later by regulation and the certification bodies.

The use of synthetic pesticides is common in the region. It is easier, needs less labor and costs less than mechanical pest control[6]. On the other hand, this is not allowed for the

**Table 7.** Labor use of organic and conventional hazelnut producers.

| | Organic ($n = 19$) | | Conventional ($n = 17$) | |
|---|---|---|---|---|
| **Labor use** | **Mean** | **Standard deviation** | **Mean** | **Standard deviation** |
| Plant care (labor hour $ha^{-1}$) | 95.6 | 44.3 | 87.0 | 69.6 |
| Harvesting (labor hour $ha^{-1}$) | 478.3 | 373.3 | 478.2 | 218.2 |
| Total (labor hour $ha^{-1}$) | 573.9 | 447.3 | 565.2 | 424.1 |
| Hired labor in plant care (%) | 63.0 | 31.0 | 64.0 | 32.0 |
| Hired labor in harvest (%)* | 74.0 | 46.0 | 61.0 | 22.0 |
| Total hired labor used (%)* | 72.0 | 47.0 | 61.0 | 41.0 |

* $P < 0.05$.

organic producers. Instead, mechanical and biological pest control methods and pest-resistant varieties are required. Sulfur is recommended for the control of the big bud mite (*Phytoptus avellanae* Nal.), as is the removal of big buds in winter[44]. There are also some organic pesticides available, such as Thuricide (*Bacillus thuringiensis*), but it is not used due to its higher cost[6]. However, organic producers have recently started using pest traps (Table 6) and applying dust lime for pests, and using mechanical control, removal of infested or damaged branches and cutting or uprooting of weeds.

## Labor

Additional labor requirement is often mentioned, in many studies, as a typical characteristic of organic farming. Padel and Zerger[45] reported a 20% higher labor requirement in Germany on organic farms, compared to conventional farms. Dubgaard[37] found that in Denmark the labor requirement of organic farms exceeds by about one-third the needs of conventional farms. Muhlebach and Muhlebach[46] reported an average 12% increase in labor requirements on organic farms in Switzerland. This difference can be explained by the type of production. Generally, vegetable production needs more labor, while livestock and fruit production require no additional labor. Some studies have shown the effect of farm size on labor requirement. In general, small farms require higher labor use per unit of land than larger farms. For example, Zerger, quoted in Padel and Zerger[45], found a decrease in the proportion of labor use as farm size increases.

In this study, labor use was measured by labor hour per hectare for different hazelnut production activities. The basic activities are plant nutrition and care (manuring, fertilizing, spraying, placing pest traps, liming, pruning, desuckering and scything) and harvest (collecting, drying, dehusking and transporting to market). These define the labor requirements for hazelnut production. Organic and conventional hazelnut producers generally apply similar inputs and plant care techniques (Table 6). For example, organic producers are not allowed to use synthetic fertilizers and pesticides. Instead of those inputs, they use manure and pest traps. Apart from this, similar plant care techniques are applied by both organic and conventional hazelnut producers. Both groups of producers use similar tools, which are generally manual equipment. The hilly topography does not facilitate mechanization[6].

As seen in Table 7, the total labor requirement of organic hazelnut production was 1.5% higher than conventional production. This was mainly due to slightly more intensive plant care activities, such as the use of farm manure, organic fertilizers and lime in organic production (Table 6). In addition, harvest comprised about 84% of the total labor needs for both groups of producers. As expected, most of the labor requirements for harvest were met by hired labor.

## Hazelnut yield, cost, price and income

Most studies have shown that organic farming systems have lower yields[21], reduced input costs, higher labor costs and additional certification costs[19,28]. Premium prices are needed to compensate for these disadvantages of organic farming. The prices of organic products are therefore higher than conventional ones in the market[14]. Producers want to learn about income, costs and price differences between organic and conventional systems before making decisions about converting farms to organic production. These economic factors are the most influential factors before and during the conversion period[47,48]. However, a premium price does not necessarily make organic production more profitable. There are other variables such as yields, prices for organic inputs, variable costs, labor requirements and farm structure which affect whole farm performance[6].

The yield of organic hazelnut producers was about 5% lower than those of the conventional producers ($P < 0.05$) (Table 8). Many studies have shown that crop yields in organic farming in general are somewhat lower than in conventional farming systems. However, in some cases similar or higher organic production yields were obtained[49]. Yield differences between organic and conventional farming systems are difficult to interpret: they may depend on many factors, such as the variety of plant, seed quality, soil type, manuring systems, length of time under organic

**Table 8.** Yield, costs, price and income of organic and conventional hazelnut production.

| | Organic ($n = 19$) | | Conventional ($n = 17$) | |
|---|---|---|---|---|
| **Yield, costs and income** | **Mean** | **Standard deviation** | **Mean** | **Standard deviation** |
| Yield (kg $ha^{-1}$)* | 904.5 | 742.1 | 949.4 | 399.6 |
| Cost (US$ $kg^{-1}$) | 2.3 | 1.0 | 2.5 | 1.6 |
| Price (US$ $kg^{-1}$) | 3.9 | 1.1 | 3.7 | 1.1 |
| Net hazelnut income (US$ $ha^{-1}$)* | 1420.4 | 738.6 | 1118.2 | 536.8 |

* $P < 0.05$.

management[18], technological development, access to information and the management skills of farmers[6]. Demiryurek found that the yield of organic hazelnuts sharply decreased during the conversion period due to lack of appropriate organic farming methods and inputs use[6]. However, the yield increased gradually after conversion and, in some cases, was even higher than conventional hazelnut production. The average yield increase of organic hazelnut production over conventional management in Turkey was 3% in 1997[6], 25% in 1999[15] and 25% in 2002[16]. On the other hand, the organic hazelnut yield was about 1.5–2.0 tons $ha^{-1}$ on an average farm, but it can reach 3.0 tons $ha^{-1}$ on intensive and highly mechanized organic farms in Italy. This yield was even higher than on conventional farms[17]. The differences in the yields in these studies may be explained by the differences in production years, location and intensity of input use.

The costs of organic hazelnut production were 8.7% lower than for conventional production (Table 8). Although total labor needs were nearly the same in both production systems (Table 7), the differences in costs were mainly due to the costs of synthetic inputs, especially pesticides, used by the conventional producers (Table 6). On the other hand, the slightly lower yield of organic hazelnut production was compensated for by the relatively higher cost of conventional production. Other studies showed that the costs in organic hazelnut production were between 4 and 6%[6,16] lower.

Product prices, from a farmer's point of view, are most important. Farmers evaluate their financial and economic performance (albeit simply) according to product prices, and then make decisions about their farming systems, level of production and even the continuity of the farm business[6].

Studies show that premium prices for organic products are available in many European countries. However, the size of the premium paid differs from product to product and country to country[50]. The premium is needed to compensate for lower yields and increased labor requirements, to equalize farm incomes and to make organic production more attractive. It is one of the most important motivation factors for conventional producers to convert to organic farming in many countries[28,29,46,50], including Turkey[47].

Even though the organic producers sold their hazelnuts for 5.4% more (3.9 US$ $kg^{-1}$) than the conventional producers (3.7 US$ $kg^{-1}$), this difference was not statistically significant ($P>0.1$). This was mainly due to the low premium prices obtained by the organic producers. Some of the organic farmers could not even sell their product as organic due to lack of demand and absence of a marketing contract with foreign buyers. Previously, the organic producers had obtained from 12 to 15% premium prices in Turkey[6,16]. In comparison, the price for organic hazelnuts in Italy was 15–20% higher than that of non-organic hazelnuts[17].

In spite of this marketing failure, the organic producers obtained a 27% higher net hazelnut income than the conventional producers ($P < 0.05$). Demiryurek[6] previously found that the organic hazelnut producers had about 16% higher gross income than conventional producers. This implies that organic hazelnut production was generally more profitable than the conventional system, although it was dependent on the premium price, which is highly affected by foreign demand, domestic supply, market crises and availability of government price supports.

Overall, the economic performance of organic and conventional farms is different. This is influenced by the type of production, yields, cost of production, level of input use, labor use and availability of premium prices.

## Summary and Conclusions

In this research, the individual characteristics, farming systems and economic performance of organic and conventional hazelnut farms in Turkey were compared. A significant point of the research is that both groups of producers were compared by cluster analysis. This analysis facilitated the definition of relatively similar farmers from both production systems and the comparison of various variables. Thus, the potential bias in comparing two different production systems and their performances was reduced or eliminated.

Understanding the economic performance of organic agriculture helps policy-makers to support organic agriculture by modifying policies and programs, and to develop markets for organic products. Specifically, knowing the characteristics of organic producers facilitates the definition of leader farmers in rural areas and can diffuse organic agriculture among producers by directing limited resources (i.e. time, finance and staff) to them. These pioneer organic

producers can serve as a model for potential organic producers. Since economic factors are the main motivation for the conversion to, and sustainability of organic agriculture, this may also facilitate conversion of land into organic agriculture by potential producers.

We concluded that organic hazelnut producers were more highly educated, allocated more time for agricultural activities and had less conventional farming experience, due to the sustained influence of organic agriculture, as compared to conventional hazelnut producers. As expected, the organic producers used more labor, especially hired labor, than conventional producers. However, this difference did not relate to the low level of mechanization in organic farming. It was mainly due to higher labor requirements for input use, especially using farm manure and manual weed control. Apart from this, the organic producers used more lime, mainly as a soil amendment. Pest traps were recently adopted by most of the organic producers.

The use of commercial organic fertilizers has been gradually increasing in organic agriculture in Turkey. The lack of livestock keeping and high labor requirements for manure distribution on hilly areas were some of the reasons. These kinds of external and commercial inputs decreased labor requirements, but organic producers became more dependent on them. This also increased the costs of production and limited the diversification of production systems on organic farms.

As far as economic performance is concerned, the organic hazelnut producers invested more capital per unit of land and obtained more income. This was mainly due to the larger size of production area owned by organic producers, i.e. economy of scale. The organic producers do not use synthetic fertilizers and pesticides, so their costs of production are relatively lower than conventional producers. On the other hand, the cost of production is not affected by labor use. Since hazelnuts are generally manually harvested by hired labor, the harvest requires the same amount of labor in both production systems.

Based on recent research and previous studies in the research area, some conclusions can be made. Since agricultural extension and training activities facilitate farmers' adoption of organic agriculture, information and technical support should be regularly provided by public agencies and private companies promoting organic production. The use of farm manure and keeping of livestock should be promoted and financially supported for organic producers. These practices enhance nitrogen cycling and increase the ecological sustainability of organic agriculture. Recent widespread use of commercial organic fertilizers and pesticides among organic producers increases their dependence on inputs from outside the farm, and threaten the economic sustainability of organic systems.

Another threat is the marketing structure of organic agriculture. Farmers' dependence on export through private marketing companies and the lack of domestic markets for local organic products endanger the economic sustainability of organic production. Hence, organic producers should be encouraged and supported to cooperate and establish their own organic farmers' unions. This cooperation could help their members to obtain their inputs at lower cost and to improve their marketing efficiency.

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# Producer participatory spring wheat variety evaluation for organic systems in Minnesota and North Dakota

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## Abstract

Organic producers in Minnesota and North Dakota, USA, indicated that they wanted to participate in hard red spring wheat (*Triticum aestivum* L. emend. Thell) variety evaluations. The objectives were to determine if a farmer–researcher developed scoring system could be used to rank wheat varieties for yield potential when grown in certified organic fields, identify views of organic producers about on-farm research, and identify the educational impact of the participatory variety evaluation process. Hard red spring wheat varieties were compared for grain yield at six locations on certified organic farms in Minnesota and North Dakota over a three-year period. A scoring system was developed and then used to identify the relative rank of adapted varieties for yield. Producers were asked to rank all varieties on a scale from 1 to 9, where 1 is lowest yield potential and 9 is highest yield potential. Producers were able to distinguish higher producing varieties as a group in 2003 and 2004. 'Oklee' a high yielding variety was ranked lowest in 2005. There was a significant linear relationship between producer ranking and yield ($P < 0.05$) even though producers could not pick the highest yielding varieties consistently in the field. The producer survey showed that grain yield, protein content, wheat scab resistance, leaf disease resistance, early seedling vigor, test weight and canopy closure were traits producers valued most in a variety. Heading date, impact on succeeding crops, straw and stubble production were ranked lower. Multi-year variety evaluation on certified organic land was highly valued by the producers surveyed. From an educational perspective, the exercise was successful in that producers had to observe individual varieties carefully in order to come to a consensus producer ranking. The model of participatory research can be used for a variety of field research projects and field days.

**Key words:** participatory research, organic wheat, yield ranking

## Introduction

Producer involvement in agricultural research is limited in crop variety development, particularly at public institutions in the USA and other developed countries. However, producer participation in agricultural research is not new. Biggs[1] provides examples of producer participatory research during the 1970s. Most examples of participatory research are from producers in marginal agricultural environments in developing nations. In the 1990s, a number of International Research Stations started to experiment with different levels of producers and breeders participation in their plant breeding programs. Joshi et al.[2] reported that rice (*Oryza sativa* L.) growers in Nepal participated in setting the goal of breeding a white-grained rice variety. Producers selected rice lines in segregating material which resulted in acceptable rice varieties for their region[3]. Sthapit et al.[3] reported that 16 producers were asked to rank seven rice varieties on a scale from 1 (excellent) to 7 (worst), incorporating positive and negative characteristics of each variety into their ranking. Producers and breeders mostly agreed upon the final ranking of the varieties. The variety rated as 'excellent' yielded the highest and the variety rated as 'worst' yielded the least of the tested varieties. Smale et al.[4] asked producers to 'vote' for previously collected maize (*Zea mays* L.) landraces that most attracted their attention. Maize preferred by producers conformed closely to the selection made by maize

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**Table 1.** Management information and plot tour data for experiments comparing 19 (in 2003 and 2004) and 13 (in 2005) hard red spring wheat varieties on certified organic fields located in Minnesota (Comstock and Fertile) and North Dakota (Richardton).

| | Comstock | | Fertile | | | Richardton |
|---|---|---|---|---|---|---|
| | 2004 | 2005 | 2003 | 2004 | 2005 | 2003 |
| Previous crop | Soybean | Soybean | Soybean | Soybean | Soybean | Winter Rye |
| Seeding date | 26-Apr | 28-Apr | 1-May | 30-Apr | 6-May | 2-May |
| Seeding rate seeds ($m^{-2}$) | 440 | 440 | 440 | 560 | 560 | 360 |
| Row width (cm) | 23 | 30 | 20 | 20 | 20 | 20 |
| Companion crop | Alfalfa | Alfalfa | None | None | None | None |
| Harvest date | 18-Aug | 29-Jul | 13-Aug | 1-Sep | 12-Aug | 14-Aug |
| Plot tour | 7-Jul | 14-Jul | 24-Jun | 23-Jun | 8-Jul | 18-Jul |
| Zadok's crop stage[15] | 6.9 | 8.5 | 5.9 | 5.7 | 7.9 | 8.8 |
| Number of groups | 4 | 5 | 4 | 4 | 4 | 4 |
| Producers per group | 10 | 7 | 6 | 6 | 8 | 9 |
| Total female participants | 4 | 3 | 3 | 4 | 5 | 4 |
| Questionnaires completed[1] | 3 | 3 | 0 | 4 | 3 | 4 |
| Traits surveys completed[1] | 3 | 2 | 0 | 4 | 3 | 2 |

[1] Not all groups were able to complete the forms within the given time and the questionnaire was not used in Fertile in 2003.

breeders[5]. Based on research data and the producers' input, elite landraces were selected. Thiele et al.[6] used questionnaires and forms to obtain knowledge about producers' interest in crop traits. Potato (*Solanum tuberosum* L.) farmers evaluated crop performance three times during the growing season, but it was found that an evaluation later in the season more closely reflected the producers' final choices.

Ceccarelli et al.[7] evaluated barley (*Hordeum vulgare* L.) grain yield measured in low and high yielding environments and concluded that the alleles which control high grain yield in low yielding conditions are at least in part different from alleles which control high grain yield in high yielding environments. They indicated that selection under stress conditions or low yielding environments may result in better-adapted materials for those systems compared with material that was only selected under high yielding environments. Disease screening, however, should take place in inoculated nurseries. Van Eeuwijk et al.[8] suggested that if producers' specific environmental conditions cannot be created at research stations, on-farm locations should be included in germplasm evaluation. In certain cases, stress (low soil fertility levels or weedy conditions) can be created at a research site. Varieties developed using the results from the managed stress and non-stress environments may provide higher yielding varieties when used under low input conditions compared with varieties developed using conventional breeding systems where selection is done under optimal growing conditions[9]. Ceccarelli et al.[10] concluded that it is possible to organize a plant breeding program with producer involvement to develop varieties adapted to a multitude of environments.

Organic producers from Minnesota and North Dakota approached university extension and research staff with the request to evaluate hard red spring wheat varieties under organic production systems because they felt that conventional testing systems (with chemical inputs) did not provide them with the information needed to make variety choices. Their requests reflect suggestions by Lammerts van Bueren et al.[11,12] that organic varieties should be bred and developed in environments managed organically. Participatory variety evaluation could be a first step in selecting adapted varieties to serve as parents in future variety development in organic production systems[13]. Participatory variety evaluation may also identify traits found to be important by producers.

Our goals were to determine if producers could identify and then rank growth traits that determined yield potential of hard red spring wheat. Our primary objectives were to determine if a farmer–researcher developed scoring system could be used to rank wheat varieties for yield potential when grown in certified organic fields. We also wanted to identify perceptions of organic producers about on-farm research and identify the educational impact of the participatory variety evaluation process. We published detailed information about the sites and wheat cultivar performance on certified organic fields in Minnesota and North Dakota[14].

## Materials and Methods

A working group consisting of organic growers, scientists and extension staff designed the experiments and selected the varieties to be included in the research. Twenty-six hard red spring wheat varieties were compared on certified organic farms near Comstock (46° 40′ N, 96° 45′ W, elevation: 284 m) and Fertile (47° 32′ N, 96° 17′ W, elevation: 349 m) in northwestern Minnesota and near Richardton (46° 53′ N, 102° 19′ W, elevation: 753 m) in southwestern North Dakota, USA, during 2003 through 2005. The experiments were located in fields prepared prior to seeding by the participating certified organic producers using standard practices on their farms, including weed control

**Table 2.** Questionnaire evaluating opinions on the importance of conducting variety adaptation studies on certified organic fields from 17 producer groups.

| Statement | Circle the answer which reflects the consensus of the group (yes or no) | Score[1] |
|---|---|---|
| 1. | It is important that variety trials be conducted in certified organic fields. | 10.0 |
| 2. | It is important that variety trials be conducted on commercial farms. | 9.3 |
| 3. | Results of trials managed with synthetic chemicals do not apply to organic environments. | 5.9 |
| 4. | It is important that weed problems are minimal where variety trials are located. | 3.6 |
| 5. | Results of variety trials are believable when generated in small research plots. | 6.1 |
| 6. | Observations from variety trials are useful without the application of statistics. | 4.6 |
| 7. | Observations from variety trials should be analyzed using statistics, and only when differences are expressed statistically can statements be made with some certainty. | 8.4 |
| 8. | A variety trial should include at least five varieties to be valid. | 7.5 |
| 9. | Variety trials should be established and maintained with commercial-scale equipment. | 5.4 |
| 10. | More than a single plot or strip of the same variety should be included in a trial. | 10.0 |
| 11. | It is important that a variety trial occur more than one year to verify an observation. | 10.0 |
| 12. | Variety trials should take less than 20 h to conduct. | 2.1 |

[1] If answer was 'yes' score is 10. If answer was 'no' score is 1. Some answers had comments and were given a score between 1 and 10 depending on the percent 'yes' and 'no' answers in the group.

(Table 1). Plots were at least 1.2 by 6.0 m and arranged in a randomized complete block with variety treatments replicated four times at each location. Small-plot research planters with disc openers were used to seed the varieties. A small-plot research combine was used to harvest mature grain from the plots and yields were standardized to a 120 g $kg^{-1}$ moisture basis.

Site visits by 24–40 organic producers and crop scientists were made to each of the six locations during late-June to mid-July when wheat was at early heading through hard dough stage of kernel development[15]. Attendees (total 12% female and 88% male) at each site were divided into groups comprised of 6–10 persons such that four groups were formed at all but one location, where five groups occurred (Table 1). Each group was given a questionnaire with several statements relating to the importance of comparing crop varieties in certified organic fields (Table 2). Groups were asked to respond, reflecting a consensus among members. A researcher or extension educator assigned to each group recorded answers after reading out loud each questionnaire statement. A score of 10 was assigned to each 'yes' and 1 to each 'no' response. Some groups could not reach a consensus and a proportional score was given between 1 and 10 depending on the percent 'yes' and 'no' answers in the group. A total of 17 completed answer sheets were used to calculate the results as not all groups were able to complete the forms within the given time and the questionnaire was not used in 2003 at Fertile.

After completing the questionnaire, the groups received a survey, designed with input from organic producers, which asked for the ranking of different wheat traits including grain yield, grain quality, straw/stubble production and the impact on succeeding crops in order of importance (1 = unimportant, 5 = very important). Participants were instructed that no more than five of the 19 traits included in the survey could be assigned the same numerical rating (Table 3).

**Table 3.** Order in which trait appeared on the survey and mean score ranking of selected traits for hard spring wheat varieties by 14 different organic producer groups in Minnesota and North Dakota, USA.

| Trait | Order in which trait appeared on the survey | Mean score[1] (1 = unimportant, 5 = very important) |
|---|---|---|
| Grain yield | 14 | 5.0 |
| Grain protein | 15 | 4.8 |
| Scab resistance | 12 | 4.6 |
| Leaf disease resistance | 11 | 4.6 |
| Early seedling vigor | 3 | 4.6 |
| Grain test weight | 16 | 4.4 |
| Canopy closure | 8 | 4.4 |
| Milling and baking | 17 | 4.3 |
| Early plant stand | 2 | 4.3 |
| Rapid emergence | 1 | 4.1 |
| Leaf size | 6 | 4.0 |
| Root disease resistance | 10 | 4.0 |
| Tillering ability | 4 | 3.7 |
| Resistance to lodging | 13 | 3.5 |
| Leaf orientation | 5 | 3.3 |
| Plant height | 9 | 2.9 |
| Heading date | 7 | 2.6 |
| Impact on succeeding crops | 19 | 2.5 |
| Straw/stubble production | 18 | 2.3 |
| Coefficient of variation (%) | | 19.7 |
| LSD 0.05 | | 0.6 |

[1] No more than 5 traits could receive the same numerical rating.

Producer groups then were assigned randomly to one of the four blocks of variety plots that comprised the field experiment. Without knowing the variety identities, each group was asked to rank all varieties in the block for growth

and yield potential using a relative system, where 1 is lowest yield potential and 9 is highest yield potential. Typically, group members first selected the variety with the lowest and highest visual yield potential in the block, after which they ranked the remaining varieties between these two extremes. A researcher or extension staff member assigned to the group recorded the rank of each variety after group members agreed by consensus on a number. Groups were allotted approximately 40 min to complete their ranking. After the ranking was completed, the identities of the varieties were revealed along with growth characteristics and yield potential from conventionally managed trials on research stations, and other factors attributed to the varieties by plant breeders. Comparisons of the four independent group rankings also occurred at that time.

Data were analyzed across those locations with common variety treatments (Fertile and Richardson in 2003 and Comstock and Fertile in 2004 with 19 variety treatments, and Comstock and Fertile in 2005 with 13 variety treatments).

The *F*-protected least significant difference (LSD) was calculated according to Steel and Torrie[16] for producer ranking, yield and yield as a percentage of block mean. As a single group of producers evaluated varieties in one block only, grain yield was expressed as a percentage of the mean of each block to calculate the linear regression with producer ranking as the independent variable and plant yield as dependent variable.

## Results and Discussion

Producers indicated unanimously (10.0) that it was important to conduct organic variety trials on certified organic fields. They also valued (10.0) replicated trials conducted for more than 1 year (Table 2). The importance of on-farm replicated and multiple year research was also reported by Wortmann et al.[17]. Plot tour participants debated the questionnaire's statements and meaning of 'commercial fields' and 'statistics' (statement 2 and 7) but mostly agreed that on-farm research (score 9.3) and statistics (score 8.4) are important. Producers mostly agreed (score 2.1) that on-farm research will take more than 20 h to conduct (statement 12).

Producers, unanimously, agreed that the most important consideration in the selection of a wheat variety is the grain yield (score 5, Table 3). Protein content, resistance to scab or Fusarium head blight caused by *Fusarium graminearum*, leaf disease resistance and early seedling vigor rated numerically as top priorities receiving scores not significantly different from those for grain yield. Plant height, date of heading, the impact of wheat on succeeding crops and straw production received lower priority in variety selection (score 2.9, 2.6, 2.5 and 2.3, respectively).

Based on comments received, producers valued the evaluation system that was used to rank varieties for their yield potential in local environments managed organically. Producers were forced to look closely at the varieties. In the survey exercise, producers previously had ranked important traits (Table 3).

**Table 4.** Year of variety release, producer group ranking for yield potential (1 is lowest yield potential and 9 is highest yield potential), actual grain yield and yield expressed as a percentage of the block mean for 19 variety treatments at Fertile and Richardson in 2003 and at Comstock and Fertile in 2004.

| Variety | Year of variety release | Producer ranking (1–9) | Grain yield (kg ha$^{-1}$) | Yield as % of block mean |
|---|---|---|---|---|
| Ingot | 1998 | 6.8 | 2980 | 111 |
| Reeder | 1999 | 6.6 | 3070 | 114 |
| AC Cadillac | 1996 | 6.1 | 2850 | 106 |
| Dapps | 2003 | 6.0 | 2840 | 103 |
| Alsen | 2000 | 5.9 | 2940 | 107 |
| oParshall[1] | 1999 | 5.8 | 2870 | 107 |
| Parshall | 1999 | 5.8 | 2730 | 100 |
| oStoa[1] | 1984 | 5.6 | 2890 | 107 |
| Red Fife | 1842 | 5.6 | 2360 | 90 |
| Walworth | 2001 | 5.5 | 3170 | 119 |
| Stoa | 1984 | 5.5 | 2890 | 106 |
| Oklee | 2003 | 5.3 | 3010 | 111 |
| Acadia | 1951 | 5.2 | 2300 | 89 |
| Waldron | 1969 | 5.1 | 2530 | 95 |
| Glupro | 1995 | 4.9 | 2030 | 74 |
| BacUp | 1996 | 4.6 | 2370 | 87 |
| Coteau | 1978 | 4.3 | 2140 | 80 |
| Chris | 1965 | 4.3 | 2310 | 87 |
| Gunner | 1995 | 4.1 | 2540 | 96 |
| Mean | | 5.4 | 2675 | 100 |
| Coefficient of variation (%) | | 36.4 | 13.0 | 11.5 |
| LSD 0.05 | | 1.4 | 241 | 8.0 |

[1] o = The seed lot was produced under certified organic conditions.

### 2003–2004

Producer rankings of the 19 varieties evaluated in 2003–2004 for grain yield were significantly different (Table 4). The highest ranking was given to 'Ingot' (6.8). The 11 entries (group within one LSD unit) which were given the highest producer ranking (mean 5.9) yielded 106% of the mean grain yield of each block scored by a group of producers (Table 4). The bottom group of 8 entries (mean 4.7 producer ranking) yielded 90% of the mean grain yield. In the first group 'Red Fife' was the only variety with lower than average yield (90% of the mean). Red Fife was the tallest (112 cm) variety. In the lower ranked group, 'Oklee' yielded 111% of the mean, and it was numerically the shortest (79.6 cm) variety. Red Fife (tallest) was ranked higher than Oklee (shortest). There are several examples where plant height obviously did not influence producer ranking for yield. For example, 'Reeder' was similar to Oklee in height (short) but producer groups ranked it high for yield (and they were correct). 'Glupro' and 'Acadia'

were ranked relatively low for yield potential but were tall varieties[14]. 'Walworth', numerically the highest yielding variety (though statistically not different from Oklee, Reeder, Ingot and 'Alsen'), received a producer ranking of 5.5. This variety had significantly more spikes (621 spikes $m^{-2}$ compared to the trial mean of 482 spikes $m^{-2}$) than any of the other varieties.

The ranking system was less useful in differentiating between varieties that ranked near the middle. Producers were asked to rank varieties for yield potential but not which traits to incorporate into their judgment. This resulted in differences of opinion between groups of evaluators, as was recorded also by Sthapit et al.[3]. In that study, producers in India ranked rice varieties at the vegetative, flowering and mature plant stages. Courtois et al.[18] reported that there was agreement among producers in India on the ranking of varieties, but unanimity about the ranking among producers was rare. Producers used barley grain yield as the main selection criterion in differentiating varieties in Syria, Morocco and Tunesia as described by Ceccarelli et al.[19]. In that study, plant height and tillering ability were also used and producers may have selected desirable combinations of traits rather than selection of one individual trait. When trained soybean (*Glycine max* L. Merr.) breeders were evaluating soybean plots for yield potential, they incorporated in their observations not only the seed yield (pods per plant) but also maturity, lodging and height[20].

## 2005

The same producer variety evaluation method was used in 2005 as in 2003–2004. The 2005 data showed no significant differences in producer ranking for yield potential (0.05 level), but there were significant differences in measured grain yield, and yield as % of block mean (Table 5). With the LSD of 1.7 (0.10 level) there is a top group of nine varieties not significantly different in producer ranking and a bottom group of four varieties. Oklee received the lowest producer score (3.3).

The producer-ranking coefficient of variation for 2005 was 42.7% compared with 36.4% for the 2003–2004 observations. This indicates that there was large variability in the scores given to the varieties all three years. There were more visual differences between the varieties in 2003–2004 compared with 2005. For instance, in 2003–2004 plant height differences ranged from 80 to 112 cm (data not reported) and yield from 2140 to 3170 kg $ha^{-1}$ compared to plant height of 70 to 85 cm (data not reported) and yields from 2410 to 2880 kg $ha^{-1}$ in 2005. It appears that producers were able to distinguish between larger observable differences among varieties during 2003–2004 compared with 2005.

## Linear relationship

We were interested to see if producers were able to predict high yielding varieties based on their visual observations.

**Table 5.** Year of variety release, producer group ranking (1 is lowest yield potential and 9 is highest yield potential), yield and yield expressed as a percentage of the block mean, for 13 wheat varieties at Comstock and Fertile in 2005.

| Variety | Year of variety release | Producer ranking (1–9) | Grain yield (kg $ha^{-1}$) | Yield as % of block mean |
|---|---|---|---|---|
| Knudson | 2001 | 6.2 | 2880 | 108 |
| Ulen | 2005 | 6.2 | 2850 | 106 |
| Steele-ND | 2004 | 5.9 | 2690 | 101 |
| Granger | 2004 | 5.8 | 2880 | 109 |
| Freyr | 2005 | 5.7 | 2710 | 102 |
| Dapps | 2003 | 5.6 | 2500 | 93 |
| Alsen | 2000 | 5.6 | 2740 | 103 |
| Hanna | 2001 | 5.3 | 2640 | 99 |
| Granite | 2001 | 4.6 | 2260 | 85 |
| Banton | 2004 | 4.3 | 2440 | 91 |
| Walworth | 2001 | 4.2 | 2780 | 105 |
| Glenn | 2005 | 4.1 | 2410 | 91 |
| Oklee | 2003 | 3.3 | 2860 | 107 |
| Mean | | 5.1 | 2665 | 100 |
| Coefficient of variation (%) | | 42.7 | 9.0 | 9.1 |
| LSD 0.10 | | 1.7 | | |
| LSD 0.05 | | NS | 224 | 8.5 |

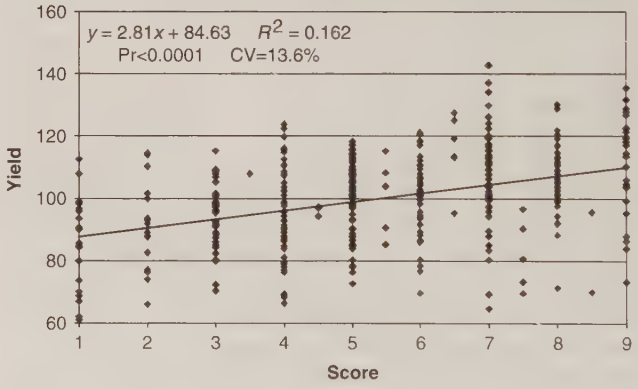


**Figure 1.** Regression of producer ranking (1 is lowest yield potential and 9 is highest yield potential) by grain yield expressed as percentage of the mean of the block evaluated by each producer group from six locations in 2003, 2004 and 2005.

In Figure 1, all producer ranking numbers of all varieties tested during 2003 through 2005 are shown. There was a significant linear relationship for higher yields with the higher producer rankings, but the *R*-squared value was only 0.16. There was also a significant linear relationship for increased crop height with higher producer rankings but with a low *R*-squared value of 0.02 (data not shown). Plant height was not considered a major wheat trait in our survey (Table 3), however, it was still a small factor in the evaluation of the varieties; this is not different from other research observations[19,20]. There was no significant linear

relationship between spikes per unit area and producer ranking (data not shown).

### Education

We compiled the data sets (all observed and recorded information) each year for winter educational meetings. Producers who had participated in the summer ranking exercise were eager to see how their ranking matched up with obtained yields. The data gathered from questionnaires, surveys and producers' ranking helped us to deliver winter meeting extension messages and information for plot tours during the following summer. One of the surprising ranking results was for Oklee (see Tables 4 and 5). The producer ranking for Oklee was relatively low in all locations, but the yield was above average. Producers apparently did not like this shorter variety and the more open canopy. It is unlikely that organic producers will adopt this variety. Knowing organic producers' preferences, from participatory variety evaluation, will help breeders and extension personnel in suggesting well-liked and adapted varieties for organic systems. Walworth had a producer ranking towards the lower end of the top group in 2003–2004 (5.5) and low in 2005 (4.2), but had an above average yield potential of 119 and 105% of the block mean in 2003–2004 and 2005, respectively (Tables 4 and 5). This variety had the highest number of spikes in 2003–2004, but the spike size was smaller (data not shown). We speculate that producers looked at the size of the heads and not at the number of heads when they ranked this variety. Researchers and extension staff often have additional agronomical information about certain varieties and may be able to interpret the ranking given by producers. In a participatory variety evaluation it will also be important to include buyers and end users of the product.

From an educational point of view, the process of using a survey first, to focus the attention of the producers on important traits, followed by the group ranking exercise and concluding with a general discussion, provided a hands-on learning setting. Those who participated in the summer event were eager to learn the yield results after harvest. This model of participatory evaluation can be used for many different crops, not only for variety identification, but also to evaluate weed control, fertility or other agronomic treatments. This approach also helped researchers and extension staff involved in the project to better understand producers' needs, thinking and way of observing the crop.

### Lessons learned

As plot tour dates had to be set some weeks in advance of the event, the timing of the ranking exercise may not have been the optimum time in the crop development for reliable variety performance prediction. Ideally, participatory evaluation of varieties may have to be done at several critical crop development stages. Filling in the questionnaire and survey may have taken too much time and some producers lost interest and enthusiasm. We tried to come to consensus answers, which proved to be challenging, and we had to incorporate the diverse views into the analysis.

The large number of varieties made it difficult to distinguish between them. Starting with ranking the variety with the lowest yield potential followed by establishing the best variety worked well and producers easily agreed upon this decision. Although we wanted to spread the scores between 1 and 9, producers ended up ranking many varieties close to the middle range (5–7), and even gave ranking scores between numbers (for instance 6.5). More training before ranking varieties may improve the ability to separate the varieties.

It is important to have a facilitator to keep the group focused and moving along. After ranking the varieties, the producers were curious to find out the names of the varieties and additional information (already known from previous research) about these varieties. It was more challenging to rank the varieties evaluated in 2005 as the phenotypic variability was less pronounced compared with the varieties evaluated in 2003–2004. We speculate that with fewer plots to evaluate, and with more observable differences between variety treatments, it would be easier for producers to come to a consensus score.

Using the participatory model may lead to unexpected results. These may be as valuable as predicting varieties with high yield potential. In our case producers indicated some varieties they did not like visually.

## Conclusion

This study demonstrated that variety adaptation research can be conducted on certified organic fields following standard experimental protocol. This project demonstrated that certified organic fields are suitable locations for conducting variety adaptation research, provided that well-planned crop rotations and other appropriate management strategies are followed. This project showed that producer-directed research efforts can be successful. Producers developed the objectives for the project, using university scientists primarily as consultants. University scientists were responsible for ensuring that field experiments were established and managed following acceptable scientific protocol, but producers were responsible for plant nutrient and pest management aspects of the research. The system of filling in a questionnaire and a survey along with ranking varieties engaged the producers in looking carefully at the plants. Farmers valued multi-year, replicated research under organic production systems. The varieties tested in 2005 were all developed through a conventional breeding program. Producers expressed the wish to incorporate specific traits, like early seedling vigor and quick canopy closure, into these varieties through a participatory plant breeding program where the next generation of varieties are selected and developed under organic field conditions and following the organic philosophy. The model of participatory variety evaluation may have potential to be used with other crops and in other locations.

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# Consumer willingness to pay for domestic 'fair trade': Evidence from the United States

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## Abstract

The success of fair trade labels for food products imported from the Global South has attracted interest from producers and activists in the Global North. Efforts are under way to develop domestic versions of fair trade in regions that include the United States, Canada and the United Kingdom. Fair trade, which is based on price premiums to support agricultural producers and workers in the Global South, has enjoyed tremendous sales growth in the past decade. Will consumers also pay a price premium to improve the conditions of those engaged in agriculture closer to home? To address this question, consumer willingness to pay for food embodying a living wage and safe working conditions for farmworkers was assessed with a national survey in the United States. The question format was a discrete choice (yes/no) response to one of four randomly selected price premiums, as applied to a hypothetical example of a pint of strawberries. Multilevel regression models indicated that respondents were willing to pay a median of 68% more for these criteria, with frequent organic consumers and those who consider the environment when making purchases most willing to pay higher amounts. Although the results should be interpreted with caution, given the well-known gap between expressed attitudes and actual behaviors, we conclude that there is a strong potential market opportunity for domestic fair trade.

**Key words:** fair trade, domestic, willingness to pay, consumers, ecolabels

## Introduction

Introduced in Europe in 1988, fair trade is a food-labeling scheme designed to support social justice and ecological sustainability in the Global South. Fair trade was brought to the USA a decade later, first for coffee and then for tea, chocolate, tropical fruits, rice and spices. High interest in fair trade is indicated by an increase in sales and the expansion of locations where fair trade products are sold. For example, the sales of coffee increased approximately 75% annually from 2001–2005, with similar growth rates for newer products[1], and distribution has expanded to the point that fair trade coffee is available at some McDonald's and many Dunkin' Donuts locations[2].

Currently, fair trade applies only to imported food products from the Global South. However, the issues that fair trade principles address—fair price, fair labor conditions, direct trade, democratic and transparent organizations, community development and environmental sustainability[3]—are also relevant to the Global North. Are consumers as willing to pay a price premium for these principles in their own countries? In other words, does domestic fair trade have the same market potential as international fair trade?

Academic studies of consumers have found a willingness to pay a price premium for fair trade coffee[4], but no comparable research exists for domestic fair trade[5]. To address the question of consumer support for domestic fair trade, we studied consumer willingness to pay premiums for a domestic product (strawberries) if it embodied basic fair trade principles of a living wage and safe working conditions for farmworkers. In this paper, we review the history of domestic fair trade, describe the research and explain the results, which indicate the level of potential consumer support for domestic fair trade.

## Domestic Fair Trade

Fair trade core business principles originated with a domestic focus on postwar European recovery and, as an alternative to free trade, was later developed as a model for improving the lives of workers in impoverished nations[6]. Since this time, fair trade has come full circle, with many

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recognizing that conditions faced by agrarian workers in the Global North parallel those of workers in the Global South. In the USA, farm labor is poorly paid, dangerous and nondemocratic. For example, of the estimated 3 million or more farmworkers in the USA[7], nearly 75% make less than $10,000 a year, more than 60% meet federal definitions of poverty[8] and many go hungry despite their daily connection to food. Farm work is also one of the most dangerous occupations in the United States[9]. Low wages and occupational risk are related to the nondemocratic nature of farm labor. In most states farmworkers do not have the right to collective bargaining or overtime[10]. Lack of labor rights has been taken to an extreme in Florida where hundreds of farmworkers have recently been found working as slaves[11]. Farmworkers receive only 6% of the retail food dollar[12]. Many farmers also struggle with low prices for their products, as the farmer share of the retail food dollar has decreased from more than 40 cents in the 1950s and early 1970s to approximately 20 cents today[13].

To address some of these injustices, a number of initiatives are in development to introduce a domestic version of fair trade in the UK, Canada and the USA. The Soil Association in the UK began testing a certified label that represents both organic and a fair price for British farmers in 2003[14]. A similar effort was initiated by the Farmer Direct Cooperative in Saskatchewan, AB, Canada in 2004[15].

In the USA there have been several 'proto-' efforts, such as The Food Alliance label and its principles, in which safe and fair working conditions are included[16]. More recently, projects that explicitly use the words 'fair trade' to refer to domestically produced foods have been established. Wholesome Harvest is a coalition of 40+ farms in the Upper Midwest that markets 'fair trade organic meats'[17]. The Local Fair Trade Network based in Minneapolis, Minnesota currently links 22 farmers with nine retailers in Minnesota and Wisconsin. The retailers sign a pledge to cover the cost of production of the farmer, and the farmers sign a pledge to pay a living wage, recognize the right to collective bargaining and provide adequate health and safety protections[18]. Equal Exchange, a pioneer of fair trade coffee imports in the USA, has introduced three 'fairly traded' products sourced from US farms—organic cranberries, organic almonds, and conventional pecans from a cooperative of African-American farmers[19]. Many of the individuals and organizations behind these efforts are involved in the Domestic Fair Trade Working Group, which has developed 14 draft principles listed in Table 1.

Despite the proliferation of these initiatives, no systematic research has been conducted on consumer support for domestic fair trade. To assess this level of support, we conducted a survey to determine the extent to which consumers were willing to pay a price premium for 'fair trade' strawberries. We focused on fresh strawberries because of their similarities to international fair trade products. Strawberries are labor-intensive, chemical-intensive and, like coffee and chocolate, are 'somewhat of a luxury' commodity, although these foods have become more available and affordable since World War II[21,22].

**Table 1.** Domestic Fair Trade Working Group draft principles.

| |
|---|
| Family scale farming |
| Capacity building for producers and workers |
| Democratic, participatory ownership and control |
| Rights of labor |
| Equality and opportunity |
| Direct trade |
| Fair and stable pricing |
| Shared risk and affordable credit |
| Long-term trade relationships |
| Sustainable agriculture |
| Appropriate technology |
| Indigenous peoples' rights |
| Transparency and accountability |
| Education and advocacy |

Source: Domestic Fair Trade Working Group (2005)[20].

Strawberries are a labor-intensive crop with a high rate of repetitive strain injuries for workers[23], and the quality of hand labor is a determinant of price at the marketplace[6]. Strawberries have a higher rate of pesticide application than almost any other crop and exposure to these chemicals contributes to both acute and chronic health problems[24].

Research has shown that a domestic fair trade type of labeling scheme could do much to improve wages and working conditions for strawberry workers. The AFL-CIO calculated that a retail price increase of just 5 cents could increase workers' wages by 40% or more[25]. The economic feasibility of such an increase has been demonstrated by Coastal Berry and Swanton Berry (an organic farm), which have contracts with the United Farm Workers union to provide higher wages and health benefits to workers in the industry[26].

In addition, consumers may be less price-sensitive, and therefore more willing to pay a premium for fresh strawberries, because they are not a staple food. Studies of willingness to pay for organic foods indicate that consumers will pay higher price premiums for more perishable products, such as fruits and vegetables, than for less perishable products like cereals[27]. How willing are US consumers to pay a fair trade premium for domestic strawberries?

## Study Methods

This question was addressed in a national survey of the United States conducted in the spring of 2006. The eight-page survey booklet on food issues was mailed to 1000 randomly selected respondents in the United States. The directions specified that the booklet should be filled out by the primary food purchaser for the household. Names and addresses were purchased from the marketing firm USADATA. We employed the Tailored Design Method[28], which involved a pre-notice letter, a survey booklet with

a $1 bill incentive, a reminder postcard and two replacement survey mailings to nonresponders, the final utilizing Priority Mail. The response rate was 51% (476 respondents excluding 62 members of the sample with undeliverable addresses).

We used a dichotomous (or discrete) choice survey question to elicit willingness to pay. This format, which involves a yes/no response to a defined amount, more closely resembles the kinds of choices people make in retail food environments than would an open-ended question[29]. However, this dichotomous format does not provide a direct measure of willingness to pay; instead it must be estimated with statistical models[30].

The question was worded 'If a pint of strawberries cost $1.50, would you be willing to pay **X** more for a pint of strawberries that **guaranteed** a living wage and safe working conditions for farmworkers?' The amount X varied depending on the version of the survey. There were four different versions of the instrument, distributed as follows: 20% were asked if they would pay 5 cents more, 30% were asked if they would pay 25 cents more, 30% were asked if they would pay 50 cents more, and 20% were asked if they would pay $1.50 more. The question response options were 'yes,' 'no' or 'not sure'. Response rates in these four groups were not significantly different ($P < 0.05$), and ranged from 49.6 to 53.4%.

The data were analyzed in multilevel logistic regression models, with individuals at one level nested inside the four bid amounts at a higher level[31]. The analysis was performed with the software HLM 6[32]. A 'yes' response for the given price option was the dependent variable. Level 1 of the analysis included this outcome and additional predictor variables measured at the individual level. Level 2 of the analysis was composed of the four different price groupings. For missing data on independent variables, multiple imputation of five datasets ($m = 5$) was performed using the program Amelia II[33], and analyzed with HLM's multiple imputation function. The first model estimated median willingness to pay for the sample. We then used bivariate models to estimate differences in willingness to pay for demographic and purchasing behavior variables. Our final model included all of the demographic and behavior variables, to simultaneously control for their influence on willingness to pay.

## Results

The demographics of the survey respondents are presented in Table 2 in comparison to US Census estimates. Respondents were more likely to be older, wealthier, of non-Hispanic white ethnicity and to have higher educational attainment than the general population. Descriptive statistics for the variables used in the analysis are reported in Table 3. There were more women (54%) than men (41%) in the sample, which was expected since women are more likely to be the primary household food purchasers. More than 17% of respondents reported purchasing organic food frequently, which we defined as at least once a week. For a question that asked if respondents consider the environment when making purchases on a 7-point scale ranging from strongly agree

**Table 2.** Survey respondent demographics compared with US Census estimates.

| Characteristic | Respondents ($n$) | | US Census 2005 estimates[1] |
|---|---|---|---|
| Women | 53.8% | (256) | 50.7% |
| Men | 41.0% | (195) | |
| Age 65+ | 17.4% | (83) | 12.4% |
| Asian | 3.8% | (18) | 4.3% |
| Latino | 6.3% | (30) | 14.4% |
| African-American | 6.1% | (29) | 12.8% |
| Native American | 1.9% | (9) | 1.0% |
| Other | 4.0% | (19) | |
| White, non-Hispanic | 76.5% | (365) | 66.9% |
| Household size | 2.62 | (mean) | 2.59 |
| Median income | 50K to 75K | (mean) | $43, 318 |
| High school diploma | 91.4% | (435) | 80.4% |
| Bachelor's degree | 39.7% | (189) | 24.4% |
| Sample size | 476 | | 296, 410, 404 |

[1] Source: US Census Bureau (2007)[34].

**Table 3.** Descriptive statistics for variables in the analyses (dichotomous unless noted).

| | Mean | SD | Percent missing |
|---|---|---|---|
| Gender | | | 5.3 |
| Men | 41.0 | | |
| Women | 53.8 | | |
| Age | | | |
| Years (continuous variable) | 51.6 | 16.0 | 7.4 |
| Ethnicity | | | 1.5 |
| White, non-Hispanic | 76.5 | | |
| Asian | 3.8 | | |
| African-American | 6.1 | | |
| American Indian | 1.9 | | |
| Latino | 6.3 | | |
| Other | 4.0 | | |
| Income | | | 11.3 |
| Low income (< $35K) | 26.9 | | |
| Middle income ($35K to $75K) | 34.9 | | |
| High income ($75K+) | 26.8 | | |
| Education | | | 4.2 |
| High school or less | 25.6 | | |
| Some college/associate degree | 30.5 | | |
| College | 25.4 | | |
| Graduate school | 14.3 | | |
| Purchasing behaviors | | | |
| Frequent organic | 17.4 | | 4.0 |
| Consider environment (7-point scale) | 4.2 | 1.7 | 6.7 |

$n = 476$

**Table 4.** Responses to willingness to pay question.

| Price premium | Yes (%) | No (%) | Not sure (%) | Total |
|---|---|---|---|---|
| 5 cents | 83 (87.4) | 5 (5.3) | 7 (7.4) | 95 |
| 25 cents | 92 (67.6) | 19 (14.0) | 25 (18.4) | 136 |
| 50 cents | 91 (67.9) | 14 (10.4) | 29 (21.6) | 134 |
| $1.50 | 32 (34.8) | 25 (27.2) | 35 (38.0) | 92 |

$n = 457$

(1) to strongly disagree (7), the mean was 4.2, or just slight disagreement.

### *How much will consumers pay for domestic fair trade?*

Responses to the willingness to pay question are reported in Table 4. For the 5-cent price premium, 87.4% of respondents were willing to pay more. The percentage declined to approximately 68% for both the 25- and 50-cent premiums, and to less than 35% for the $1.50 price premium. The percentage of both 'no' and 'not sure' responses increased approximately 5 times from the lowest price premium to the highest. While 5.3% were unwilling to pay 5 cents more, 27.2% were unwilling to pay $1.50 more. The 'not sure' responses increased from 7.4 to 38% for the same amounts.

Results of the multilevel model with no predictor variables are shown in Table 5. The median willingness to pay for domestic fair trade strawberries was $1.02 more than the base price of $1.50 (+68%).

### *Who is most willing to pay for domestic fair trade?*

Bivariate associations with willingness to pay a price premium are listed in Table 6. Most other ethnic groups were more willing than white, non-Hispanic respondents to pay more. The largest difference observed between ethnic groups was that Asian/Pacific Islanders were willing to pay 25% more than white, non-Hispanic respondents. There was a similar strength of association for women—they were willing to pay 37 cents (25%) more than men.

The variables associated with the largest differences in willingness to pay were the two purchasing behaviors. Those who consider the environment when making purchases were willing to pay 21 cents (14%) more for every one unit increase on this 7-point scale. For example, those who strongly agreed with a statement that they engage in this behavior are estimated to be willing to pay $1.47 more than those who strongly disagree. Frequent organic consumers also demonstrated notable differences; they were 3 times more likely than other consumers to be willing to pay more for domestic fair trade, an estimated 69 cents more.

The full model, which controls for all of these variables simultaneously, is reported in Table 7. Most relationships were weaker when compared with the bivariate models, with the exception of education and some ethnic groups. When controlling for other variables in the model, there was a stronger negative relationship between years of education and willingness to pay a price premium. Respondents with postgraduate degrees were willing to pay a median of 56 cents less than respondents without schooling beyond high school. Those with some college or an associate degree were not as willing to pay more in comparison to respondents who had never attended college (19% less). College graduates demonstrated a similar association, though the difference between this group and those with a high school education was weaker and did not reach conventional levels of statistical significance (13% less, $P = 0.19$). Asian/Pacific Islanders were predicted to be willing to pay a median of 39 cents more than white, non-Hispanics, an increase of 2 cents when compared with the bivariate model. In the 'other' ethnic category, willingness to pay went from 9 cents less than white, non-Hispanics in the bivariate model, to 12 cents less in the full model.

Purchasing behaviors maintained the strongest associations with willingness to pay more, although the relationships were slightly attenuated when compared with those reported in the bivariate models. Respondents who stated that they purchased organic foods at least weekly were willing to pay 42% more for a living wage and safe working conditions than those who do not, compared with 46% in the bivariate model. For considering the environment when making purchases, each one-unit increase on this scale was associated with an 11% increase in willingness to pay a premium, compared with 14% in the bivariate analysis. Those who strongly agree with this question are

**Table 5.** Multilevel logistic regression model of willingness to pay.

| Fixed effects | Coefficient | OR | 95% CI | *P* | Cents | % More |
|---|---|---|---|---|---|---|
| Level 1 | | | | | | |
| Intercept | 1.491 | | | 0.01 | 102 | 68 |
| Level 2 | | | | | | |
| Price | −0.015 | 0.99 | 0.98–0.99 | 0.00 | | |
| **Random effects** | **Variance component** | | | *P* | | |
| Intercept variance | 0.366 | | | 0.02 | | |

$n = 457$

**Table 6.** Bivariate multilevel logistic regression models of willingness to pay.

| | Coefficient | OR | 95% CI | *P* | Cents | % More |
|---|---|---|---|---|---|---|
| Gender | | | | | | |
| Men (reference) | | | | | | |
| Women | 0.552 | 1.74 | 1.65–6.81 | 0.00 | 37 | 25 |
| Age | | | | | | |
| Years | −0.002 | 0.99 | 0.98–1.01 | 0.67 | 0 | 0 |
| Ethnicity | | | | | | |
| White, non-Hispanic (reference) | | | | | | |
| Asian/Pacific Islander | 0.555 | 1.74 | 1.09–2.79 | 0.02 | 37 | 25 |
| Latino/Hispanic | 0.378 | 1.46 | 0.87–2.44 | 0.15 | 25 | 17 |
| African-American/Black | 0.300 | 1.35 | 0.53–3.45 | 0.53 | 20 | 13 |
| Other | −0.142 | 0.87 | 0.61–1.23 | 0.42 | −9 | −6 |
| Income | | | | | | |
| Low income (reference) | | | | | | |
| Middle income | −0.404 | 0.67 | 0.41–1.01 | 0.06 | −27 | −18 |
| High income | −0.554 | 0.57 | 0.41–0.71 | 0.00 | −37 | −25 |
| Education | | | | | | |
| High school or less (reference) | | | | | | |
| Some college/associate degree | −0.359 | 0.70 | 0.39–1.26 | 0.24 | −24 | −16 |
| College graduate | −0.130 | 0.88 | 0.65–1.20 | 0.41 | −9 | −6 |
| Postgraduate degree | −0.738 | 0.48 | 0.22–1.06 | 0.07 | −50 | −33 |
| Purchasing behaviors | | | | | | |
| Frequent organic | 1.097 | 3.00 | 1.36–6.62 | 0.01 | 69 | 46 |
| Consider environment (7-point scale) | 0.322 | 1.38 | 1.24–1.53 | 0.00 | 21 | 14 |

$n = 457$

thus predicted to be willing to pay $1.12 more than those who strongly disagree, after controlling for other variables.

Women were willing to pay a median of 12% more than men, half the difference noted in the bivariate model. The association between high income and willingness to pay was also weaker, but remained negative. Compared with the low-income group, those with annual household incomes above $75,000 would pay a median of 29 cents less. Age was not associated with willingness to pay for a living wage and safe working conditions.

## Discussion

The two purchasing behavior variables, buying organic weekly and considering the environment, were associated with the highest percentage increases in willingness to pay for strawberries that embodied a living wage and safe working conditions for farmworkers. This suggests that efforts to establish domestic fair trade should begin by targeting retail outlets frequented by these types of consumers. Cooperative food stores and buying clubs are particularly promising options since they have contributed substantially to the growth of organic and international fair trade food sales, in large part due to the ethical commitments of their owners and customers[35]. Two-thirds of the participating retailers in the Local Fair Trade Network are food cooperatives[18]. However, if domestic fair trade is to expand beyond a small niche, it will need to branch out into more mainstream outlets in the same way that international fair trade has done. Two possibilities include Whole Foods Market and Trader Joe's chains, both of which stock substantial amounts of organic and international fair trade products[36,37].

Some of the most interesting associations were that respondents with the most years of education and the highest incomes, when controlling for other variables, were *less* willing to pay for domestic fair trade criteria. This goes against conventional wisdom that more affluent people will pay more and that more educated people are more interested in sustainability. Definitely, those with higher incomes could more easily afford a price premium since they pay a much lower percentage of their incomes for food than do low-income people. We can only speculate that these findings may be in part due to the socio-economic status differences that create social distance from those with lower incomes and/or fewer years of education. That is, farmworkers may receive less sympathy from those who may not relate to their plight[38]. The results may have been different if we had also included criteria related to a fair price for farmers, given the idealization of the family farm[16,39] and the pervasiveness of farm-centric agrarian ideologies in the USA[6].

One well-known limitation of willingness to pay studies has been termed the 'attitude behavior gap', which means that purchasing behaviors do not correspond to stated intentions[4,40]. Typically, stated willingness to pay is higher than actual behaviors[41]. For example, the market share of

**Table 7.** Multivariate multilevel logistic regression model of willingness to pay.

| Fixed effects | Coefficient | OR | 95% CI | *P* | Cents | % More |
|---|---|---|---|---|---|---|
| Level 1 | | | | | | |
| Intercept | 1.145 | | | 0.13 | 64 | 43 |
| Gender | | | | | | |
| Men (reference) | | | | | | |
| Women | 0.315 | 1.37 | 1.06–1.76 | 0.02 | 18 | 12 |
| Age | | | | | | |
| Years | −0.007 | 0.99 | 0.98–1.01 | 0.31 | 0 | 0 |
| Ethnicity | | | | | | |
| White, non-Hispanic (reference) | | | | | | |
| Asian/Pacific Islander | 0.708 | 2.03 | 1.19–3.47 | 0.01 | 39 | 26 |
| Latino/Hispanic | 0.081 | 1.08 | 0.69–1.70 | 0.72 | 5 | 3 |
| African-American/Black | 0.077 | 1.08 | 0.56–2.08 | 0.82 | 4 | 3 |
| Other | −0.214 | 0.81 | 0.58–1.12 | 0.20 | −12 | −8 |
| Income | | | | | | |
| Low income (reference) | | | | | | |
| Middle income | −0.254 | 0.78 | 0.47–1.28 | 0.32 | −14 | −9 |
| High income | −0.514 | 0.60 | 0.40–0.89 | 0.01 | −29 | −19 |
| Education | | | | | | |
| High school or less (reference) | | | | | | |
| Some college/associate degree | −0.503 | 0.60 | 0.40–0.91 | 0.02 | −28 | −19 |
| College graduate | −0.357 | 0.70 | 0.41–1.20 | 0.19 | −20 | −13 |
| Postgraduate degree | −1.000 | 0.37 | 0.18–0.75 | 0.01 | −56 | −37 |
| Purchasing behaviors | | | | | | |
| Frequent organic | 1.130 | 3.09 | 1.23–7.77 | 0.02 | 63 | 42 |
| Consider environment (7-point scale) | 0.291 | 1.34 | 1.21–1.48 | 0.00 | 16 | 11 |
| Level 2 | | | | | | |
| Price | −0.018 | 0.98 | 0.98–0.99 | 0.00 | | |
| **Random effects** | **Variance component** | | | ***P*** | | |
| Intercept variance | 0.373 | | | 0.03 | | |

$n = 457$

fair trade products in most European countries is far lower than the level of support expressed in surveys[42]. However, a high willingness to pay among even a small proportion of the population may indicate the potential for a highly profitable niche market[30].

Another limitation of this study is that we chose a product that was amenable to domestic fair trade criteria and marketing, with attributes that would make it more likely that consumers would be willing to pay more than the standard price (i.e. a fresh fruit considered to be a non-essential or pleasure food). Therefore these results should not be taken to mean that consumers are willing to pay more for domestic fair trade versions of all food products.

## Conclusions

Consumers in the United States indicate that they are willing to pay substantially more for strawberries that embody a living wage and safe working conditions. Considering the environment when making purchases, or purchasing organic foods on a weekly basis was associated with a willingness to pay the largest additional amounts for these attributes. While these results should be interpreted with caution given the well-known gap between attitudes and actual behaviors, they do express a promising potential market for domestic fair trade efforts.

Future research is needed to evaluate the effectiveness and economic viability of specific projects such the Local Fair Trade Network and Equal Exchange's 'fairly traded' products to improve conditions for farmers and farmworkers. In addition, assessing willingness to pay for other food products is needed, as this is likely to differ substantially for different commodities. It would also be interesting to compare support for international and domestic fair trade and to study whether there are differential levels of support for price premiums for farmers and farmworkers. Finally, qualitative research is needed to shed light on the reasons underlying the demographic differences such as income and education that affect willingness to pay a price premium for domestic fair trade.

The current level of interest expressed in domestic fair trade is impressive, particularly given the fledgling nature of these efforts and the limited awareness of international fair trade in the United States. Our results indicate that domestic fair trade labeling schemes may be a viable means of addressing some of the inequities in the US food system. Certainly, market-based approaches to resolving agrifood system issues have both promise and pitfalls, as we have seen with the organic label[43,44]. For example, willingness to pay depends on ability to pay, and not all have the ability[45]. However, research on demographics associated with purchasing organic fresh produce (which is much more abundant than for other ecolabels, such as fair trade) indicates that income has become essentially irrelevant—people from all income levels are almost equally likely to be willing to pay price premiums averaging up to 78% more than conventional produce[46]. Even so, if the number of willing buyers constrains the size of the market to a small niche, only a limited number of farmers and farmworkers will realize the price premium[47]. While fair trade and organic labels often fall short of their ideals in practice, they do have positive impacts and the potential to lead to more transformative changes as part of a more comprehensive strategy for achieving social justice and ecological sustainability[43–45, 47–49]. Our study shows strong potential support for including domestic fair trade as part of an overall strategy for working toward social justice in the agrifood system.

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# Economizing the use of nitrogen fertilizer in wheat production through enriched compost

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## Abstract

Manipulation of organic wastes and their composts as a source of organic matter (OM) and nutrients is imperative for sustainable agriculture. Further, the fortification of composts with chemical fertilizer enhances agronomic effectiveness of both by reducing the amount of fertilizer and improving the quality of compost. The present study aimed to explore the potential of organic and chemical nutrient sources with their optimal application and integration for sustainable wheat production. Accordingly, waste fruits and vegetables were collected, dried, ground and processed in a composting vessel. During the enriched composting, waste material (300 kg) was fortified with 30 kg N, i.e. 25% of the standard rate (120 kg N $ha^{-1}$) of N fertilizer. Treatments for both greenhouse and field experiments using wheat (*Triticum aestivum* L.) included: control (without any compost or N fertilizer), compost (non-enriched), fertilizer N 120 (120 kg N $ha^{-1}$), nitrogen-enriched compost (NEC), NEC + N 30 (30 kg N $ha^{-1}$) and NEC + N 60 (60 kg N $ha^{-1}$). Application rate of composts (non-enriched or enriched) was 300 kg $ha^{-1}$ in the respective treatments. Phosphorus and potassium fertilizers were applied at 90 kg $P_2O_5$ $ha^{-1}$ and 60 kg $K_2O$ $ha^{-1}$, respectively in all treatments. The crop was grown to maturity, and data on wheat growth and yield attributes were recorded. Application of NEC significantly improved the growth, yield and N, P and K contents of wheat compared with compost and control treatments. The performance of NEC + N 60 was statistically similar to that of fertilizer N 120. Economic analysis also revealed the superiority of NEC + N 60 over other treatments in terms of net return and relative increase in income; however, the value/cost ratio was highest with NEC alone. For effective and economical use of N fertilizer, it is suggested to integrate N fertilizer at reduced rates with NEC. Through enriched compost, application rates can be decreased from tonnes to kilograms per hectare, and dependence on chemical fertilizer can be reduced to a certain extent. So the approach is farmer friendly as it lowers compost application rates, and is economically acceptable as it saves N fertilizer. It is also environmentally sustainable due the recycling of organic waste and possible reduction of N losses to the environment. Thus, the study has wide application in the global environment and fertilizer market.

**Key words:** organic wastes, fortified compost, growth and yield, nutrient uptake, economics, environmental pollution

## Introduction

Massive waste (agricultural, industrial, urban) generation, increased management costs and heightened public awareness about the environment and health safety have compelled agricultural, industrial and municipal sectors towards safe disposal of organic residues. Huge amounts of organic materials are in the form of farm waste, city waste, sewage sludge, poultry litter and agro-industrial wastes[1,2]. In urban areas of Pakistan, less than 60% waste is collected as no city has a proper waste collection and disposal system[3]. Improper handling of these wastes results in several environmental risks such as pollution of soil, water and air[4]. Composting, compared with other management strategies like landfilling, incineration and dumping in water channels, is a more economical and ecologically acceptable way to tackle the problem[5,6]. It helps to dispose of waste hygienically and also conserve the valuable plant nutrient source for safe use in agriculture[5].

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**Table 1.** Analysis of raw and composted fruit and vegetable wastes.

| Material/ Contents | Carbon (C) | Nitrogen (N)[1] | Phosphorus (P) | Potassium (K) | Zinc | Copper | Iron | Manganese | C/N ratio | C/P ratio | C/K ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | ------- | ----------%---------- | | | ----------μg $g^{-1}$---------- | | | | | | |
| Raw waste | 32.4 | 1.39 | 0.26 | 1.19 | 38.6 | 1.14 | 368 | 43.1 | 23.3 | 125 | 27.2 |
| Compost | 23.2 | 2.41 | 0.39 | 1.72 | 48.4 | 1.37 | 598 | 57.8 | 9.60 | 60 | 13.5 |

[1] Nitrogen content of enriched compost was 12.0%.

Composting is a biological process that converts heterogeneous organic wastes into stable and humified organic material by mixed microbial population under controlled optimum conditions of moisture, temperature and aeration. Organic matter (OM) thus biodegraded during composting can be handled, stored and applied to land without any environmental impact[6–9]. Composted organic material can be used as a source of OM and plant nutrients for sustainable crop productivity. The composted organic wastes not only act as a supplement to chemical fertilizers, reducing the need of inorganic fertilizers, but may also improve the OM status and physico-chemical properties of soil[10–12].

No doubt, use of chemical fertilizers provides essential nutrients for crop improvement to obtain higher yields and composted organic materials improve soil health, but during recent decades the yields have become almost static, for example in India and China[13]. It is more likely that the fortification of composted organic materials with chemical fertilizers may be an effective alternative approach for improving crop yields beyond existing levels. The quality of compost as well as the efficiency of chemical fertilizer was improved through enrichment of composted organic materials with urea N fertilizer during composting[14,15]. Incorporation of an appropriate rate of urea-N also reduced the quantity of applied organic waste substantially, contrary to the use of tonnes $ha^{-1}$ for improvement of crop productivity as reported by many scientists[16–18]. Organic fertilization has advantages from both environmental and economic perspectives, and with appropriate application rates, chemical fertilizers could be reasonably avoided or minimized, lowering the production costs and reducing groundwater pollution without decreasing yields[19]. Organic production produces beneficial impacts on social and environmental issues, in addition to high prices fetched by the organic produce[20].

In this study, waste fruits and vegetables were composted and fortified with urea fertilizer to make nitrogen-enriched compost (NEC). Lower rates of N fertilizer were applied along with NEC to enhance the N fertilizer efficiency and to improve growth, yield and nutrient uptake of wheat. Further, economic evaluation of these nutrient sources was undertaken as it is an essential basis for farmer adoption of compost use. The focus was to optimize the use of both the compost and N fertilizer, so that any environmental pollution potential could be reduced without lowering crop yields and soil productivity.

## Materials and Methods

This study comprises two phases; enriched compost was prepared in the first phase, and wheat crop was grown with compost and N fertilizer during the second phase. Two parallel experiments on wheat crop production with the same treatments were performed, one in the greenhouse and the other in the field at the Agronomy Field Station of Ayub Agriculture Research Institute (AARI), Faisalabad, Pakistan during 2004–2005.

### *Preparation of enriched compost*

Compost was prepared by using a locally fabricated composter consisting of a drier, crusher/grinder and a processor. Organic material containing fruit and vegetable wastes was collected from various locations (fruit and juice shops, fruit and vegetable markets, etc.) of Faisalabad city. The collected organic waste material was air-dried for 24 h to remove the excess moisture and sorted to remove all unwanted substances (plastic bags, glass material and stones, etc.) in the organic waste. The organic material was then oven-dried at 60 ± 5°C for 24 h and crushed in the crushing unit of the composter to convert raw forms of the waste into a finer form (< 2 mm). The crushed material was put in the composter (processing unit; a vessel of 500 kg capacity) to convert organic waste materials into compost. A moisture level of 40% (v/w) of the compost was maintained during the composting process. Composting was done for 6 days under controlled temperature and aeration (shaking at 50 rpm). The temperature rose up from 30 to 70°C in the composting unit during 2nd and 3rd day of composting and then reduced gradually to 30°C after 5th day process.

Composted material (300 kg) was fortified with 25% of the recommended rate (120 kg $ha^{-1}$) of N fertilizer for wheat in the form of urea. Thus, the 300-kg batch of compost received 30 kg N for the wheat crop. After enrichment, the organic product was passed through a grinder to make granules of the product. The enriched compost was packed in gunny bags and stored for a few days prior to use.

Both raw (non-composted) and composted organic waste materials were analyzed on a dry weight basis (Table 1) for carbon content[21], and macro- and micronutrients[22]. The C/N, C/P and C/K ratios were determined.

**Table 2.** Effect of different nutrient sources on growth and yield of wheat in the greenhouse.

| Treatments | Plant height (cm) | Tiller (no.) (plant$^{-1}$) | Spike length (cm) | Straw yield (g pot$^{-1}$) | Grain yield (g pot$^{-1}$) | 1000-grain weight (g) |
|---|---|---|---|---|---|---|
| Control | 54.3 c* | 2.0 d | 7.9 d | 14.3 d | 6.9 d | 35.3 d |
| Compost | 55.6 c | 2.0 d | 8.1 cd | 17.2 c | 7.8 d | 37.2 c |
| Fert N 120 | 61.0 a | 4.1 a | 9.2 ab | 24.0 a | 12.0 a | 40.4 a |
| NEC alone | 57.1 b | 2.6 c | 8.5 bc | 19.0 bc | 9.5 c | 39.2 b |
| NEC+N 30 | 60.6 a | 3.4 b | 8.8 b | 20.6 b | 10.6 b | 40.0 b |
| NEC+N 60 | 61.5 a | 4.2 a | 9.6 a | 23.6 a | 12.2 a | 41.0 a |

* Values sharing the same letter(s) in a column do not differ significantly at $P < 0.05$.

### *Greenhouse experiment*

This experiment was conducted in pots in a greenhouse to assess the effect of enriched compost and chemical fertilizers on the growth and yield of wheat crop. Soil was collected from Agronomy Station fields of AARI, Faisalabad; it was air-dried, ground, sieved (2 mm) and analyzed for physical and chemical characteristics. The soil used for the pot trial was a sandy clay loam having pH 7.4; ECe 2.8 dS m$^{-1}$; OM, 0.71%; total N, 0.05%; available P, 6.9 mg kg$^{-1}$; and exchangeable K, 180 mg kg$^{-1}$ soil. Each pot was filled with sieved soil (10 kg pot$^{-1}$), mixed with recommended P and K fertilizers at 90 and 60 kg ha$^{-1}$, respectively. Single super phosphate and sulfate of potash were used as a source of P and K. Both types of composts (non-enriched or enriched) were applied on a dry weight basis at the rate of 300 kg ha$^{-1}$ by mixing it with the top 15 cm soil before filling the pots. A standard rate of N at 120 kg ha$^{-1}$ for wheat was kept for comparison. Details of the treatments are given below:

(T1) Control (without any compost or N fertilizer)
(T2) Compost (non-enriched)
(T3) Urea fertilizer nitrogen applied at 120 kg N ha$^{-1}$ (Fert N 120)
(T4) NEC alone
(T5) NEC + 30 kg N ha$^{-1}$ (NEC + N 30)
(T6) NEC + 60 kg N ha$^{-1}$ (NEC + N 60)

Eight seeds of wheat (*Triticum aestivum* L.) of the cultivar Inqulab-91 were sown in each pot containing 10 kg soil. After germination, four healthy and uniform plants were maintained in each pot. The pots were arranged in completely randomized design with four replications. An additional amount of N fertilizer (25 and 50%) was applied in solution as two split applications. The first and second applications were applied after thinning and at grain-filling stage. Canal water meeting the irrigation quality criteria[23] for crops was used for irrigation.

### *Field experiment*

The field experiment was conducted to assess the effect of enriched compost and chemical fertilizers on the growth, yield and nutrient uptake of wheat, which was sown at 125 kg seed ha$^{-1}$ with a hand-drill, with an inter-row distance of 25 cm, with individual treatment plots of 12 m$^2$ (4 m × 3 m). The soil had the same physico-chemical characteristics as in the pot trial. The treatment plan followed was the same as in the case of the green-house experiment. The experiment was laid out in randomized complete block design with four replications. The N, P and K fertilizers were applied at 120, 90 and 60 kg ha$^{-1}$ as urea, single super phosphate and sulfate of potash, respectively.

Full amounts of P and K fertilizers were applied as a basal dressing at sowing time to all treatments, while N was applied in two split applications, i.e. in the 3rd week after germination and at the tillering stage, according to the treatment plan. The effectiveness of organic fertilizer (NEC) was assessed in the presence of 25 and 50% of full application of N fertilizer for wheat. Compost-based organic fertilizer was applied at 300 kg ha$^{-1}$ as a side dressing to plants along with the first application of N fertilizer and was then irrigated with canal water.

The plants were harvested at maturity (both in pot and field trials) and the growth and yield data were recorded. The NPK contents in grain and straw were determined[22]. The total nutrient contents of wheat plants (uptake) were calculated. The data were processed statistically through analysis of variance[24]. Means were compared by the Duncan's Multiple Range test[25].

### *Economic analysis*

Data on the expenditures and returns of various treatments were processed for their economic comparison by using the procedures given hereunder[26]: Net return = Value of increased yield obtained − Cost of nutrient sources; Value/cost ratio (VCR) = Value of increased yield obtained ÷ Cost of nutrient sources; Relative increase in income (RII) = (Net income/Income at control) × 100.

## Results

### *Greenhouse experiment*

NEC in combination with N fertilizer increased the yield and yield attributes of wheat significantly (Table 2). By comparison with the control and compost alone, application of NEC caused a significant improvement in plant height, with no differences between N application rates. Similarly, NEC increased plant tillers at the 50 and 100% N

enrichment, while compost alone was no better than the control. The effect of the materials on spike length was similar to plant height and tillers, but the influence of N enrichment rate was inconsistent.

Straw and grain yield, the main parameters of concern, and 1000-grain weight of wheat were also affected significantly by the integrated use of NEC and chemical fertilizer. For both straw and grain yield, the order of the effects of the materials was as follows: control, compost alone, NEC, and the NEC with three levels of N. In each case, there was no significant difference between the second and third N application rates along with NEC. The effects on 1000-grain weight were similar, being 35.3 g (lowest) for the control and 41.0 g (highest) for the NEC along with 60 kg N $ha^{-1}$.

As expected, the NEC in the presence of N fertilizer caused significant increase in N, P and K contents over control (124.6, 153.7 and 102%, respectively), but did not differ significantly with full dose of N fertilizer alone (Table 3). The compost alone without any enrichment was not different from the control.

### *Field experiment*

Application of NEC in combination with N fertilizer significantly increased the plant height, number of tillers $m^{-2}$, spike length, straw yield, grain yield and 1000-grain weight of wheat (Table 4). The response patterns for most parameters followed those observed in the greenhouse experiment. Grain and straw yields with the NEC plus the two higher N levels were 2–3 times higher than the control without any compost or nutrient addition. In each case, NEC with higher N levels was significantly superior to NEC alone with no difference between second and third N application rates. The same results were observed in the case of the control and compost alone.

The NEC in the presence of 50% N fertilizer caused significant increase in N, P and K contents (192.7, 220.5 and 188.3%, over the control, respectively) of wheat that differed non-significantly with full application rate (100%) of N fertilizer (Table 5). Application of non-enriched compost and control also had non-significant difference.

**Table 3.** Effect of different nutrient sources on nutrient uptake (mg $pot^{-1}$) by wheat in the greenhouse.

| Treatments | Nitrogen | Phosphorus | Potassium |
|---|---|---|---|
| Control | 154 d* | 67 d | 117 d |
| Compost | 190 d | 83 d | 136 d |
| Fert N 120 | 355 a | 165 a | 239 a |
| NEC alone | 245 c | 110 c | 170 c |
| NEC+N 30 | 296 b | 133 b | 201 b |
| NEC+N 60 | 346 a | 170 a | 237 a |

* Values sharing the same letter(s) in a column do not differ significantly at $P < 0.05$.

## Discussion

This study demonstrated the effectiveness of NEC combined with chemical fertilizer for promoting the growth, yield and nutrients (N, P and K) uptake of wheat under both greenhouse (pot) and field conditions. A relatively low application of NEC combined with standard application rates of fertilizer N was shown to increase N-use efficiency. With the application of 300 kg $ha^{-1}$ organic fertilizer/enriched compost (compost enriched with 30 kg N), there was an overall ~25% (30 kg) saving of N. Other scientists[16,27,28] also reported N saving with the application of compost; however, most studies used larger amounts of compost as a complementary source to chemical fertilizer in contrast with our study. Thus, the actual N rate applied was the same as the full recommended application of chemical fertilizer, but part of the chemical fertilizer was substituted through the compost.

The novelty of our approach is that the NEC was applied just at 300 kg $ha^{-1}$ as a soil amendment. Previously, farmers had to add compost in soil at several tonnes per hectare, largely because of the poor nutrient status of such compost. It is likely that N losses due to leaching or denitrification might have been reduced in soil by mixing N-fertilizer with organic compost, resulting in a better utilization of N by the plant[14,15]. Previous studies have also shown that composted organic materials enhance fertilizer use efficiency by releasing nutrients slowly and thus reducing the losses, particularly of N[16,29–31].

Recently, an incubation study revealed that carbon dioxide release from NEC-amended soil was much slower than recorded in the case of raw compost or raw compost

**Table 4.** Effect of different nutrient sources on the growth and yield of wheat in the field.

| Treatments | Plant height (cm) | Tillers (number $m^{-2}$) | Spike length (cm) | Straw yield (tonnes $ha^{-1}$) | Grain yield (tonnes $ha^{-1}$) | 1000-grain weight (g) |
|---|---|---|---|---|---|---|
| Control | 60.5 d* | 324 d | 8.2 d | 2.65 d | 1.93 d | 39.7 d |
| Compost | 67.4 cd | 352 cd | 8.5 cd | 2.80 d | 2.06 d | 41.0 cd |
| Fert N 120 | 84.2 a | 442 ab | 9.9 a | 6.02 a | 3.95 a | 45.5 ab |
| NEC alone | 73.3 bc | 380 c | 8.8 c | 4.48 c | 3.25 c | 42.6 c |
| NEC+N 30 | 79.2 ab | 424 b | 9.4 b | 5.81 ab | 3.69 b | 44.4 b |
| NEC+N 60 | 87.1 a | 460 a | 10.1 a | 6.25 a | 4.0 a | 46.2 a |

* Values sharing the same letter(s) in a column do not differ significantly at $P < 0.05$.

plus urea-amended soil, indicating more stability of composted organic wastes over uncomposted organic wastes[32]. It was also reported that organic material rich in N is least decomposed/lost, adding more OM to the soil[33]. Since addition of organic fertilizer increases mobilization of P and microbial activities in soil[34], it might also be a contributing factor in improving P nutrition as well as improving the root system.

The results also revealed that application of non-enriched compost at 300 kg $ha^{-1}$ without any N fertilizer had no significant effect on the growth and yield of wheat and was comparable with the un-amended control. This was probably due its poor nutrient content and slower decomposition rate. Application of immature compost (raw organic waste) at considerably higher application rates (tonnes) may even reduce the crop yield due to a wider C/N ratio, oxygen deficiency in plant roots and production of harmful organic compounds[18,34–36].

The economic analysis of the study (Table 6) indicated that this technology of N-amended compost is cost-effective, as collection and transportation of waste organic material are the government's responsibility by law. Raw material is available free of cost and application of a few hundred kilograms is quite feasible for farmers to use as soil amendments; also it does not create a demand–supply problem. This approach is not only cost-effective but also helps in saving chemical fertilizer and improving the soil OM status and thus soil quality. As the production cost of N fertilizer is considerable both in its environmental aspects (consumption of fossil fuel and emission of $CO_2$) as well as in currency terms, there is increasing demand from the global society and farmers, especially in developing countries, for optimal and profitable N-resource management practices. Nitrogen losses through leaching (nitrate) and in gaseous forms (nitrous oxide and ammonia) from agricultural lands, particularly from fertilizer N sources (ranging up to 60%), also have a negative environmental impact and an economic loss. This situation emphasizes the need to develop viable technologies and farm practices leading to enhanced N fertilizer use efficiency that centers on optimizing application and minimizing uncontrolled losses.

OM plays a pivotal role in stabilizing N through biological intervention so as to reduce its losses and improve its efficiency in crop production. Organic farming has a considerable potential to contribute to the global food supply, and also to reduce the harmful effects on environment from conventional agriculture[37]. With respect to biodiversity, atmospheric pollution and water contamination, the organic system was found to be superior to the integrated system, which in turn was better than the conventional method of olive farming[38]. Our study supports this dual objective. By introducing the NEC technology, the amount of N fertilizer could be reduced by at least 25% of the total required to sustain crop yields. With appropriate manure application, the advantages of organic fertilization were reflected in chemical fertilizers being reasonably avoided in sweet pepper cultivation, thus lowering production costs without decreasing fruit yield[19]. Thus organic production can have beneficial impacts on social and environmental issues, in addition to a potentially higher price for such produce[20].

**Table 5.** Effect of different nutrient sources on nutrient uptake (kg $ha^{-1}$) by wheat in the field.

| Treatments | Nitrogen | Phosphorus | Potassium |
|---|---|---|---|
| Control | 30.4 d* | 14.1 d | 39.4 d |
| Compost | 33.6 d | 15.6 d | 47.0 d |
| Fert N 120 | 88.8 a | 43.6 a | 115.4 a |
| NEC alone | 55.2 c | 27.9 c | 80.8 c |
| NEC+N 30 | 78.4 b | 38.0 b | 101.8 b |
| NEC+N 60 | 89.0 a | 45.2 a | 113.6 a |

* Values sharing the same letter(s) in a column do not differ significantly at $P < 0.05$.

**Table 6.** Economics (in US$) of using different nutrient sources for wheat production in the field.

| Treatments | Expenditure on nutrient sources[1] | Income from wheat[2] | | | Increased income over control | Net Return | Value/cost (VCR) ratio | Relative increase in income (RII) |
|---|---|---|---|---|---|---|---|---|
| | | Grain | Straw | Total | | | | |
| Control | – | 321.67 | 66.25 | 387.92 | – | – | – | – |
| Compost | 3.00 | 343.34 | 70.00 | 413.34 | 25.42 | 22.42 | 8.47 | 93.89 |
| Fert N 120 | 43.48 | 658.35 | 150.50 | 808.85 | 420.92 | 377.44 | 9.68 | 183.72 |
| NEC alone | 17.29 | 541.68 | 112.00 | 653.68 | 265.75 | 248.46 | 15.37 | 148.48 |
| NEC+N 30 | 28.16 | 615.01 | 145.25 | 760.26 | 372.34 | 344.18 | 13.22 | 172.68 |
| NEC+N 60 | 39.03 | 666.68 | 156.25 | 822.93 | 435.01 | 395.98 | 11.15 | 186.92 |

[1] Expenditures on different nutrient sources were as follows:
- Price of N fertilizers (US$ $kg^{-1}$) = 0.36 (NFDC, 2006)[39].
- Cost of NEC includes electricity and labor charges for processing.
- Cost of enriched compost includes electricity and labor charges for processing, and cost of 30 kg N.

[2] Price of the wheat produce is as follows:
- Price of wheat grain = 166.67 US$ $tonne^{-1}$.
- Price of wheat straw = 25.00 US$ $tonne^{-1}$.

## Conclusions

Organic waste materials can be converted into value-added organic fertilizer by composting and fortification with lower doses of urea N. It is possible to get higher yield levels with complementary use of organic and synthetic fertilizers, as against their sole application. The improvement in soil OM and reduction in piling up of organic wastes would be an additional incentive. Further, the reduced demand for mineral N fertilizers may lessen the consumption of a non-renewable energy source (natural gas) used as raw material for urea fertilizer production, and would keep down the pollution from emissions of greenhouse gases ($CO_2$ and nitrous oxide) and leaching of nitrates to groundwater. Also, the resource-poor farmers, especially in developing countries like Pakistan, could be less reliant on expensive mineral N fertilizers to support their livelihoods from their limited agricultural income.

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# Organic amendment effects on tuber yield, plant N uptake and soil mineral N under organic potato production

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## Abstract

The market for certified organic potatoes in Canada is growing rapidly, but the productivity and dynamics of soil N under commercial organic potato systems remain largely unknown. This study examined, at two sites in Atlantic Canada (Winslow, PEI, and Brookside, NS), the impacts of organic amendments on Shepody potato yield, quality and soil mineral nitrogen dynamics under organic management. Treatments included a commercial hog manure–sawdust compost (CP) and pelletized poultry manure (NW) applied at 300 and 600 kg total N $ha^{-1}$, plus an un-amended control (CT). Wireworm damage reduced plant stands at Brookside in 2003 and those results are not presented. Relatively high tuber yields (~30 Mg $ha^{-1}$) and crop N uptake (112 kg N $ha^{-1}$) were achieved for un-amended soil in those site-years (Winslow 2003 and 2004) when soil moisture was non-limiting. Compost resulted in higher total yields than CT in one of three site-years. Apparent recovery of N from CP was negligible; therefore CP yield benefits were attributed to factors other than N availability. At Winslow, NW300, but not NW600, significantly increased total and marketable yields by an average of 5.8 and 7.0 Mg $ha^{-1}$. Plant available N averaged 39 and 33% for NW300 and NW600, respectively. Soil (0–30 cm) $NO_3^-$-N at harvest was low (< 25 kg N $ha^{-1}$) for CT and CP, but increased substantially both in season and at harvest (61–141 kg N $ha^{-1}$) when NW was applied. Most leaching losses of $NO_3^-$-N occur between seasons and excessive levels of residual soil $NO_3$-N at harvest, as obtained for NW600, must be avoided. Given current premiums for certified organic potatoes, improving yields through application of amendments supplying moderate rates of N or organic matter appears warranted.

**Key words:** organic production, potato, soil mineral N, apparent N recovery, plant available N, organic amendments

## Introduction

Organic farming and retail sales of organic food products in North America have been characterized by strong annual growth rates over the past 20 years[1]. In Canada, the market for certified organic potatoes (*Solanum tuberosum* L.) is growing rapidly with insufficient supply to meet domestic demand[2]. As production expands, there will be a need to evaluate the effectiveness of current management practices for organic potato production. Organic potato production is typically characterized by extended rotations involving leguminous crop green manures sometimes combined with organic amendments. Losses due to insects and pest damage and overall low quality, however, typically reduce organic potato yields to an average of 50–75% that of conventional production[3–5]. Yield uncertainty in organic potato production may also promote post-harvest N losses through leaching[6]. A life cycle assessment of the potential environmental impact of organic potato production in Sweden suggested that environmental benefits would be increased through improving yields and tuber quality and reducing nitrous oxide emissions associated with organic potato production[5]. Little is known, however, about the productivity and efficiency of nitrogen use in commercial organic potato production in Canada and how these production systems impact on potato tuber yield and quality.

Nitrogen is critically important for canopy development, tuber initiation and yield of potato[7,8]. The increasing availability of commercially produced organic amendments approved for use in organic production, such as composts and dehydrated pelletized manures, may change the intensity of N use in organic potato production systems. The efficient

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use of all such sources of N in potato production is required to minimize negative impacts on water and air quality and increase the economic return on the crop[9,10] but few comparative studies exist on the impacts of contrasting organic amendments on potato tuber yield and quality. The slow release of N from organic amendments may reduce the risk of nitrate leaching early in the growing season. Moreover, studies in other systems have noted the 'non-nutrient' benefits of organic nutrient sources in improving soil structure and organic matter[11,12], water-holding capacity and root development[13] and soil microbial activity[14]. Evidence that soil organic amendments may be used to enhance potato yields has been presented as early as the 1970s[15], when it was noted that manure increased potato yields and that the effect was probably due to improved cation-exchange capacity, organic matter content and water-holding capacity, rather than effects on nutrient supply. Little is known about the N use efficiency, soil mineral N dynamics and the environmental risks associated with organic potato production, and no research has been conducted on N cycling in organically managed potato soils in Atlantic Canada. The objective of this study was to evaluate processing potato yields and quality, and soil mineral N dynamics, under nonirrigated commercial organic production in Atlantic Canada, as affected by contrasting organic amendments.

## Materials and Methods

A 2-year (2003–2004) field study was established on a commercial organic farm located in Winslow, Prince Edward Island, and on the Brookside organic agriculture experimental site at the Nova Scotia Agricultural College (NSAC), Truro, Nova Scotia. Soils at the Winslow site were a Charlottetown sandy loam (Orthic Humo-Ferric Podzol) and at the Brookside site were a Pugwash sandy loam (Orthic Humo-Ferric Podzol)[16,17]. At the Winslow site, the potato plots in each year followed a preceding wheat crop, within the typical 4-year rotation sequence (2 years grass/clover perennial forage followed by grain and potatoes) maintained by the farm operator. Limited rotation options were available at the newly established Brookside site and preceding crops were long-term (~20 year) pasture in 2003, and grain in 2004. At the Brookside site, losses due to wireworm damage reduced plant stands by up to 30% in 2003, and the results for that year are not presented. Daily air temperature and precipitation was recorded at each site by an automated data logger with air temperature sensor and tipping bucket (Campbell Scientific Corp., Edmonton, Alberta, Cananda). The physical and chemical properties of the test soils are presented in Table 1.

The experiment used a randomized complete block design (RCBD) with 5 treatments and 4 replicates. Treatments included an un-amended control and two contrasting organic amendments approved for use in certified organic production: a commercial hog manure-sawdust compost (CP; Atlantic Country Composting, Antigonish, Nova Scotia, Canada) and a pelletized dehydrated poultry manure [Nutriwave 4-1-2 (NW); Envirem Technologies, Fredericton, New Brunswick, Canada], each applied at 300 and 600 kg total N $ha^{-1}$ (CP300, CP600, NW300 and NW600). The compositions of the two organic amendments are provided in Table 2. We estimated that 30% of the total N applied as Nutriwave would be plant available in the year of application, i.e. 100 and 200 kg N $ha^{-1}$ for treatments NW300 and NW600, respectively. A secondary objective of the research (data to be presented elsewhere) was to test a novel technique (*in situ* anion/cation-exchange membranes) for predicting plant available N (PAN) from soil and organic amendments. The latter treatment, NW600, was expected to provide available N in excess, but was included for this purpose. The compost, in contrast, because of the relatively high C/N ratio, was expected to supply much less PAN than the Nutriwave. Phosphorus (P) and potassium (K) were supplied as Sulpomag (0-0-22) and Calphos rock phosphate (0-3-0) as required by soil test. Application rates of Calphos were 2.3 t $ha^{-1}$ at Brookside in 2004, and 3.5 and 5.8 t $ha^{-1}$ at Winslow in 2003 and 2004, respectively. Sulpomag was applied at 0.490 t $ha^{-1}$ to supply 108 kg K $ha^{-1}$ at Brookside in 2004 and 0.743 t $ha^{-1}$ to supply 165 kg K $ha^{-1}$ at Winslow in 2003 and 2004. All amendments and supplemental P and K fertilizers were broadcast and incorporated by disking 1 day prior to planting by hand. Each plot consisted of 10 m of 4 rows of potatoes with 0.91 m between-row and 0.3 m within-row spacing. Trials were planted with hand-cut generation E1

**Table 1.** Initial physical and chemical properties of soils at the Winslow and Brookside sites in 2003 and 2004.

| | Winslow | | Brookside |
|---|---|---|---|
| **Parameter** | **2003** | **2004** | **2004** |
| Soil pH | 5.8 ± 0.0[1,2] | 7.0 ± 0.2[2] | 6.0 ± 0.1[2] |
| Sand (g $kg^{-1}$) | 557 ± 10[3] | 590 ± 51 | 732 ± 25 |
| Silt (g $kg^{-1}$) | 301 ± 10 | 263 ± 47 | 183 ± 52 |
| Clay (g $kg^{-1}$) | 143 ± 2 | 146 ± 7 | 85 ± 32 |
| Organic matter (%) | 3.6 ± 0.2[4] | 3.7 ± 0.1 | 3.5 ± 0.4 |
| $NO_3$-N (kg $ha^{-1}$) | 15.6 ± 3.3[5] | 46.5 ± 3.9 | 45.0 ± 26.7 |
| $NH_4$-N (kg $ha^{-1}$) | 19.8 ± 7.5 | 28.8 ± 5.1 | 11.1 ± 5.1 |
| P (mg $kg^{-1}$) | 40.0 ± 4.7 | 65.4 ± 8.2 | 110.0 ± 43.3 |
| K (mg $kg^{-1}$) | 62.9 ± 5.1 | 70.3 ± 7.2 | 212.5 ± 66.0 |
| Ca (mg $kg^{-1}$) | 1234.0 ± 125.3 | 1779.0 ± 144.0 | 2716.1 ± 163.3 |
| Mg (mg $kg^{-1}$) | 115.5 ± 8.3 | 100.0 ± 7.8 | 575.2 ± 19.3 |

[1] pH is measured in 0.01 M $CaCl_2$ with a soil/solution ratio of 1 : 2.
[2] Values are means ($n = 4$) ± standard deviation, of composite (1 per replicate) soil (0–30 cm) samples collected 10–14 days prior to planting at each site.
[3] Particle-size distribution is measured by the hydrometer method[40].
[4] Organic matter is determined by wet oxidation[41].
[5] Soil P, K, Ca and Mg contents are measured by Mehlich III extraction[42].

**Table 2.** Composition of organic amendments used in 2003 and 2004.

| | Pelletized dehydrated poultry manure 'Nutriwave' | | Hog manure–sawdust compost | |
|---|---|---|---|---|
| **Property**[1] | **2003** | **2004** | **2003** | **2004** |
| DM ($g\,kg^{-1}$) | 976.3[5] | 979.5 | 330.7 | 442.6 |
| C/N ratio | 8.7 | 10.1 | 21.6 | 15.5 |
| Total N[2] ($g\,kg^{-1}$) | 44.4 | 38.6 | 11.3 | 13.9 |
| $NH_4$-N[3] ($g\,kg^{-1}$) | 6.1 | 6.8 | 1.7 | 1.6 |
| Total P[4] ($g\,kg^{-1}$) | 14.7 | 12.2 | 3.4 | 4.2 |
| Total K[4] ($g\,kg^{-1}$) | 18.9 | 16.2 | 4.4 | 6.1 |
| N/P ratio | 3.0 | 3.2 | 3.3 | 3.3 |
| N/K ratio | 2.4 | 2.4 | 2.6 | 2.3 |

[1] With the exception of DM, all analyses are expressed on a dry matter basis.
[2] Total C and N content determined by dry combustion (LECO CNS-1000)[43].
[3] Mineral N content of water extracts determined by a segmented flow autoanalyzer[43].
[4] Total P and K content determined by inductively coupled plasma (ICP) following nitric acid digestion of dried samples[43].
[5] Values are means ($n = 4$) ± standard deviation.

seed of cultivar Shepody (McCain Produce Inc., Florenceville, New Brunswick, Canada). Regionally, optimum inorganic fertilizer N application rates for this cultivar following small grains are in the order of 200 kg N $ha^{-1}$.[7,18]

Potatoes were planted on 9 June 2003 and 2 June 2004 at the Winslow site, and on 27 May 2004 at the Brookside site. Hills were re-shaped mechanically at approximately 30 days after planting (DAP). Weeds were controlled until hilling by hand weeding. Late blight and Colorado potato beetle were controlled by using copper hydroxide (Parasol) and Bt (Novador), respectively, as required. Total copper applied as Parasol at each site ranged between 2.8 and 5.6 kg Cu $ha^{-1}$. Vines were killed by mowing and plots were machine harvested 2 weeks later using a one-row digger. Biomass and N uptake of shoot, root and tuber were determined just prior to topkilling through recovery of 4 plants per plot[19]. Potatoes were harvested on 7 October 2003 and 22 September 2004 at the Winslow site and on 15 September 2004 at the Brookside site. Fresh weight yields were measured from 8 m of row taken from the center two rows in each plot. A 25 kg sample of tubers was retained and stored at 9°C until graded for size, defects and then sub-sampled for determination of dry matter and specific gravity. Tubers were sized in accordance with the Canadian Agricultural Standard Act for processing potatoes; small is 38–51 mm, Canada no. 1 size is 51–89 mm, large ('Jumbo') size is 89–114 mm and culls are < 38 mm[20].

The dynamics of soil nitrate ($NO_3^-$-N) in the 0–30 cm depth layer were gauged from soil samples (a composite of 10 × 2.5 cm diameter cores per replicate in spring, or per plot thereafter) collected repeatedly (i.e. approximately every 3 weeks) until topkilling and following tuber harvest. Samples were immediately frozen until analyzed. Samples were extracted with 2 M KCl[19]. The $NO_3^-$ and $NH_4^+$ concentrations of the extracts were determined by molecular absorption spectroscopy in a segmented flow system (Technicon Industrial Systems Corp., Tarrytown, New York). We assumed a soil bulk density of 1.0 mg $m^{-3}$ to convert inorganic N concentrations measured at planting and post-harvest to units of kg N $ha^{-1}$.[21] The apparent N recovery (ANR) was determined as the difference in whole plant N uptake between amended and un-amended plots expressed as a percentage of total N applied, i.e.

$$\text{ANR}(\%) = [(\text{N uptake for treatment} - \text{N uptake for unfertilized control})/\text{N applied}] \times 100$$

PAN from organic amendments was calculated as ANR, plus gain of soil residual mineral N at harvest relative to the control expressed as a percentage of total N applied, i.e. PAN (%) = [((N uptake for treatment − N uptake for unfertilized control) + (seasonal change in soil N mineral N for treatment))/N applied] × 100.

Normality distribution of data was checked and logarithmic transformations were made when necessary. Because of partial changes in the composition of both organic amendments between years, analysis of variance (ANOVA) was performed separately for each site-year using the GLM procedure[22]. The basic difficulty here was that there were only 2 (source) × 2 (rate) + 1 (control) unique treatments and these did not comprise a complete 2 × 3 factorial design. A correct analysis of such experiments was previously demonstrated[23,24]. A 5 × 1 RCBD model was set to separate treatment means at first, followed by a 2 × 2 factorial RCBD model excluding the control to further explore the effects of source and rate of organic amendments. Two orthogonal contrasts involving control were created to differentiate the control and others. Next, a univariate repeated-measure ANOVA, after sphericity test, was carried out for the soil nitrate variable by integrating time effect in the model as an independent variable to assess the interaction of sampling time with treatment.

## Results and Discussion

### *Seasonal temperature and rainfall*

In 2003, 328 mm of rain fell at Winslow during the 5-month period of June to October, approximately 10% less than the

**Table 3.** Significant levels[1] of ANOVA for planned variables over all three site-years.

| Source[2] | Total tuber yield | Marketable tuber yield | Jumbo+ Canada no. 1 | Specific gravity | Mean tuber weight | Tuber N content | Plant N content | Tuber N concentration | Soil $NO_3$-N concentration |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | **Winslow 2003** | | | | |
| Treatment (T) | *** | *** | *** | *** | * | ** | *** | ** | *** |
| CT versus CP | * | * | * | ns | * | ns | ns | ns | * |
| CT versus NW | * | * | ns | *** | ns | * | ** | *** | *** |
| Source (S) | *** | *** | *** | *** | ns | *** | *** | *** | *** |
| Rate (R) | ns | ns | * | ** | * | ns | ns | ns | * |
| S × R | ns | ns | ns | ns | ns | * | * | ns | * |
| | | | | | **Winslow 2004** | | | | |
| Treatment | ns | ns | ns | *** | ns | *** | *** | *** | *** |
| CT versus CP | ns | ns | ns | ns | ns | * | ns | ns | ns |
| CT versus NW | ns | ns | ns | *** | ns | *** | *** | *** | *** |
| Source (S) | ns | ns | ns | *** | * | *** | *** | ** | *** |
| Rate (R) | ns | ns | ns | ns | ns | ns | ns | ns | *** |
| S × R | ns | * | ns | ns | ns | ns | ns | ns | *** |
| | | | | | **Brookside 2004** | | | | |
| Treatment | * | nd | ** | ** | * | ns | *** | *** | *** |
| CT versus CP | ** | nd | ** | ns | ns | ns | *** | ns | ns |
| CT versus NW | ns | nd | ns | *** | * | ns | *** | *** | *** |
| Source (S) | ** | nd | ** | ** | * | ns | * | *** | *** |
| Rate (R) | ns | nd | ns | ns | ns | ns | ns | ns | * |
| S × R | ns | nd | ns | ns | ns | ns | ns | ns | * |

[1] *, ** and ***, significant at $P < 0.5$, 0.01 and 0.001, respectively; ns, not significant at $P < 0.05$; nd, not determined.
[2] CT, un-amended control; CP, hog manure–sawdust compost; NW, pelletized poultry manure 'Nutriwave'.

30-year average of 361 mm distributed well across all 5 months. Average monthly temperatures, with the exception of September (+3°C), closely followed (±1°C) the 30-year average for this location. In 2004, at the same site, 340 mm of precipitation fell during the same period. Temperatures were slightly cooler than average in June (13.7°C compared with 15.3°C) but followed closely the 30-year average for the remainder of the season. Annual temperatures at Winslow in 2003 and 2004 averaged 5.7 and 5.3°C, respectively, whereas total precipitation (snow plus rainfall) totaled 1024.2 and 986.8 mm, respectively. At Brookside, 294 mm of rain fell from June to October 2004, well below (−24%) the 30-year average of 385 mm. Much of this deficit (64 mm) occurred during the first 2 months (June and July) of the season. Monthly average temperatures during the season compared closely (±1°C) with 30-year averages for this site, with the exception of the month of June, which was notably cooler (12.7°C compared with a 30-year average of 15.1°C). The annual temperature at Brookside in 2004 averaged 5.6°C, whereas total precipitation totaled 1247.1 mm.

### *Tuber yield*

At the Brookside site, tuber yields (21.5 Mg ha$^{-1}$, on average across treatments) were 30% lower than the average yield recorded at the Winslow site in either year. The lower yields at the Brookside site are most likely attributable to the early season moisture deficit in 2004. In Maine[25] a 36–37% increase in yield (cv. Superior) was obtained through supplemental irrigation over 2 years when rainfall amounts fell to 323 and 217 mm from June to October. In an Atlantic Canada study[18], the response of Shepody to applied N was also greater with irrigation than without, and was reflected in both increased number of tubers per plant and average fresh tuber weight. In site years (Winslow 2003 and 2004) when seasonal soil moisture levels were non-limiting, the relatively high tuber yields (29.9 ± 2.2 Mg ha$^{-1}$) for the un-amended control plots were reflective of the long rotations (4-year+) characteristic of organic potato production. In station-based trials[26] average tuber yields of 34.5 Mg ha$^{-1}$ were reported for Shepody fertilized with P and K but not N.

The effects of organic amendments on tuber yields varied over the three site-years (Table 3). The hog manure–sawdust compost significantly decreased total tuber and marketable yields in 2003 at the Winslow site (Table 4), presumably attributable to a strong net immobilization of soil N promoted by the compost characterized by a high C/N ratio of 21.6 (Table 2). Solid manures with C/N above 15 : 1 have been reported to decrease N availability in the short term[27,28], while negligible net N mineralization has been found for composts with C/N of greater than 22 : 1[29]. In 2004 at Brookside, total tuber yields in the compost plots were significantly higher than the un-amended control (Tables 3 and 4) but, as discussed below, the increases in

**Table 4.** Potato tuber yield, marketable yield, tuber size, mean tuber weight and specific gravity over the three site-years.

| Treatment[1] | Tuber yield (Mg ha$^{-1}$) | Marketable tuber yield (Mg ha$^{-1}$) | Jumbo + Canada no. 1[2] (Mg ha$^{-1}$) | Specific gravity (g) | Mean tuber weight (g) |
|---|---|---|---|---|---|
| | | | **Winslow 2003** | | |
| CT | 28.2 | 25.7 | 23.9 | 1.089 | 168 |
| CP300 | 23.3 | 21.3 | 19.0 | 1.090 | 152 |
| CP600 | 19.7 | 18.0 | 14.3 | 1.086 | 137 |
| NW300 | 35.4 | 33.0 | 30.8 | 1.079 | 164 |
| NW600 | 31.9 | 29.8 | 26.2 | 1.072 | 138 |
| SEM ($n = 4$) | 2.0 | 2.1 | 2.2 | 0.003 | 6.8 |
| | | | **Winslow 2004** | | |
| CT | 31.6 | 23.2 | 29.5 | 1.098 | 163 |
| CP300 | 34.4 | 22.1 | 31.7 | 1.092 | 164 |
| CP600 | 35.7 | 27.4 | 33.4 | 1.093 | 159 |
| NW300 | 36.0 | 29.8 | 32.4 | 1.077 | 149 |
| NW600 | 32.9 | 22.2 | 29.2 | 1.071 | 147 |
| SEM ($n = 4$) | 1.7 | 4.1 | 1.6 | 0.003 | 8.2 |
| | | | **Brookside 2004** | | |
| CT | 19.4 | nd[3] | 15.5 | 1.077 | 117 |
| CP300 | 24.0 | nd | 19.9 | 1.074 | 119 |
| CP600 | 24.1 | nd | 19.7 | 1.072 | 114 |
| NW300 | 20.8 | nd | 16.6 | 1.065 | 106 |
| NW600 | 19.3 | nd | 14.4 | 1.062 | 91 |
| SEM ($n = 4$) | 1.2 | nd | 1.2 | 0.002 | 7.4 |

[1] CT, un-amended control; CP300 and CP600, hog manure–sawdust compost applied, respectively, at 300 and 600 kg total N ha$^{-1}$; NW300 and NW600, pelletized poultry manure 'Nutriwave' applied, respectively, at 300 and 600 kg total N ha$^{-1}$; SEM, standard error of the mean.
[2] Jumbo, 89–114 mm; Canada no. 1, 51–89 mm.
[3] nd, not determined due to wireworm reduction in marketable yield.
Summary of statistical analyses of data is provided in Table 3.

tuber yields were not accompanied by increases in tuber or plant N content at topkill (Table 5).

Application of the pelletized poultry manure at the rate of 300 kg total N ha$^{-1}$ (NW300) significantly and consistently increased total tuber and marketable yields at the Winslow site, with average increases over 2 years of 5.8 and 7.0 Mg ha$^{-1}$ in tuber total and marketable yields compared with the un-amended control (Tables 3 and 4). However, the yield response was not observed at the higher rate application (600 kg N ha$^{-1}$) of Nutriwave (NW600). While tuber number differed little between Nutriwave treatments (187 (NW300) versus 203 (NW600); data not shown), NW600 resulted in mean tuber weights much smaller than the unfertilized control probably due to delayed plant maturity and tuber fill as a result of excessive N supply (Table 4)[30].

Reductions in marketable yields from total tubers at the Winslow site varied substantially between years, with losses more apparent in 2004 than 2003 (Table 4). These were primarily due to scab (average ~30% of tubers) with culls and other defects accounting for less than 5% of tubers. At 7.0, soil pH of un-amended soil at this site in 2004 was notably high (Table 1), a factor which undoubtedly contributed to the greater incidence of scab recorded. At the Brookside site in 2004, most tubers, irrespective of treatment, showed some incidence of wireworm damage and this was reflected in greatly reduced marketable yields (Table 4). Nutriwave, but not compost, significantly decreased tuber specific gravity in all three site-years. The tuber size distribution was variable in the compost plots, with Canada no. 1 and Jumbo size tubers significantly lower at the Winslow site in 2003 but greater at Brookside in 2004, as compared with the un-amended control (Table 4).

With conservative estimated gross wholesale returns of can$400 per Mg, a 20% yield gain (in the order of 5.0 Mg ha$^{-1}$) in response to compost and the Nutriwave amendments would produce added returns of approximately can$2,000 ha$^{-1}$ before culling losses. At the application rates used in this study and costs in the range of can$100 Mg$^{-1}$ for the Nutriwave and can$30 Mg$^{-1}$ for compost, amendment costs would be in the range of can$700 ha$^{-1}$. As noted below, however, we underestimated PAN from Nutriwave by up to 9%. Given current premiums for certified organic potatoes, enhancing yields through application of organic amendments which supply N or organic matter appears warranted. It can be argued that such imports constitute a 'substitution' for synthetic sources by organic systems[31]. A central principle of organic systems is a commitment to regional recycling of nutrients, however, and given the benefits of organic amendments to soil physical, chemical and biological properties, the use of

**Table 5.** Tuber N concentration, tuber and whole plant N accumulations, ANR and PAN measured at topkill over the three site-years.

| Treatment[1] | Tuber N concentration (%) | Tuber N uptake (kg ha$^{-1}$) | Plant N uptake (kg ha$^{-1}$) | ANR (% of total N applied) | PAN (% of total N applied) |
|---|---|---|---|---|---|
| | | | **Winslow 2003** | | |
| CT | 1.15 | 63.4 | 83.3 | – | |
| CP300 | 1.21 | 62.9 | 85.8 | 0.8 | 1.2 |
| CP600 | 1.07 | 46.7 | 64.7 | −3.1 | −4.1 |
| NW300 | 1.57 | 93.2 | 142.3 | 19.7 | 29.1 |
| NW600 | 1.77 | 120.5 | 200.9 | 19.7 | 42.6 |
| | | | **Winslow 2004** | | |
| CT | 1.07 | 71.9 | 112.5 | – | |
| CP300 | 1.03 | 87.1 | 130.3 | 5.9 | 3.5 |
| CP600 | 1.19 | 83.7 | 125.0 | 2.1 | 1.9 |
| NW300 | 1.55 | 116.9 | 210.2 | 32.6 | 41.1 |
| NW600 | 1.70 | 123.1 | 221.8 | 18.2 | 32.0 |
| | | | **Brookside 2004** | | |
| CT | 1.23 | 67.0 | 139.5 | – | |
| CP300 | 1.28 | 65.9 | 132.6 | −2.3 | −4.2 |
| CP600 | 1.10 | 62.5 | 104.0 | −5.9 | −2.4 |
| NW300 | 1.64 | 74.4 | 213.6 | 24.7 | 45.4 |
| NW600 | 1.73 | 70.5 | 225.5 | 14.3 | 23.1 |

[1] CT, un-amended control; CP300 and CP600, hog manure–sawdust compost applied, respectively, at 300 and 600 kg total N ha$^{-1}$; NW300 and NW600, pelletized poultry manure 'Nutriwave' applied, respectively, at 300 and 600 kg total N ha$^{-1}$.
Summary of statistical analyses of data is provided in Table 3.

such materials can be considered consistent with the overall objectives of production system 'redesign' espoused within certified organic industry standards, as noted elsewhere[32]. Organic production systems are criticized for potentially mining reserves of phosphorus and potassium[33], and an over-reliance on imported phosphate rock as the primary soil P amendment[34]. Consideration of the use of regionally available organic amendments in organic production systems must also be made within that context.

## Crop N uptake and ANR

Crop N uptake measured at topkilling in un-amended soils averaged 112 kg N ha$^{-1}$ (Table 5). This is significantly higher than an average of 85 kg N ha$^{-1}$ uptake by potatoes receiving no N fertilizer on 56 farm sites in Atlantic Canada, and slightly greater than the 105 kg N ha$^{-1}$ uptake reported specifically for Shepody following red clover[26]. In un-amended control plots, tuber N represented 62% of total plant N uptake, well within the range of 53–78% N harvest index reported for Shepody fertilized, in station-based trials, with P and K but not N[26].

Although the tuber N accumulation and total plant N uptake were complicated by a source by rate interaction in the Winslow site in 2003 (Table 3), the tuber N and total plant N uptake in the pelletized poultry manure treatments were generally considerably higher than the un-amended control and the compost plots in all three site-years, except for tuber N at Brookside in 2004 where the effects were depressed by yield suppression caused by a moisture deficit (Table 4). The Nutriwave effects were also reflected in elevated tuber N concentrations (Tables 3 and 5), most evident under the high application rate (NW600). Tuber nitrate has been found to increase substantially for Shepody at tuber N contents greater than 1.6%[18] although the relationship between them appears very field- and year-specific[35]. In Germany, increased tuber nitrate in organically managed potatoes was obtained when farmyard manure was supplied at 160 and 240 kg N ha$^{-1}$.[36]

Typically, where mineral fertilizer N is applied to potatoes, approximately 45% of this N is recovered in potato tubers[37,38]. With increasing rate of the Nutriwave, 52 and 49% of plant N, respectively, was recovered in tubers (Table 5). Over all site-years, the ANR of amendments averaged from 1.5 to −2.3% for CP300 and CP600 and 26 to 17% for NW300 and NW600, respectively (Table 5). The negligible N benefit of the compost treatments even when promoting a yield response at Brookside in 2004 was notable, suggesting that the compost acted as soil amendment rather than as a nutrient source. A growing body of reports[11–14] suggests that for composts in particular, the 'non-nutrient' benefits to soil physical, chemical and biological properties, such as improvements in soil structure and organic matter, water-holding capacity and microbial activities, are primarily responsible for observed increases in potato yields. Potatoes are a shallow rooted crop, and even small improvements in soil moisture holding capacity

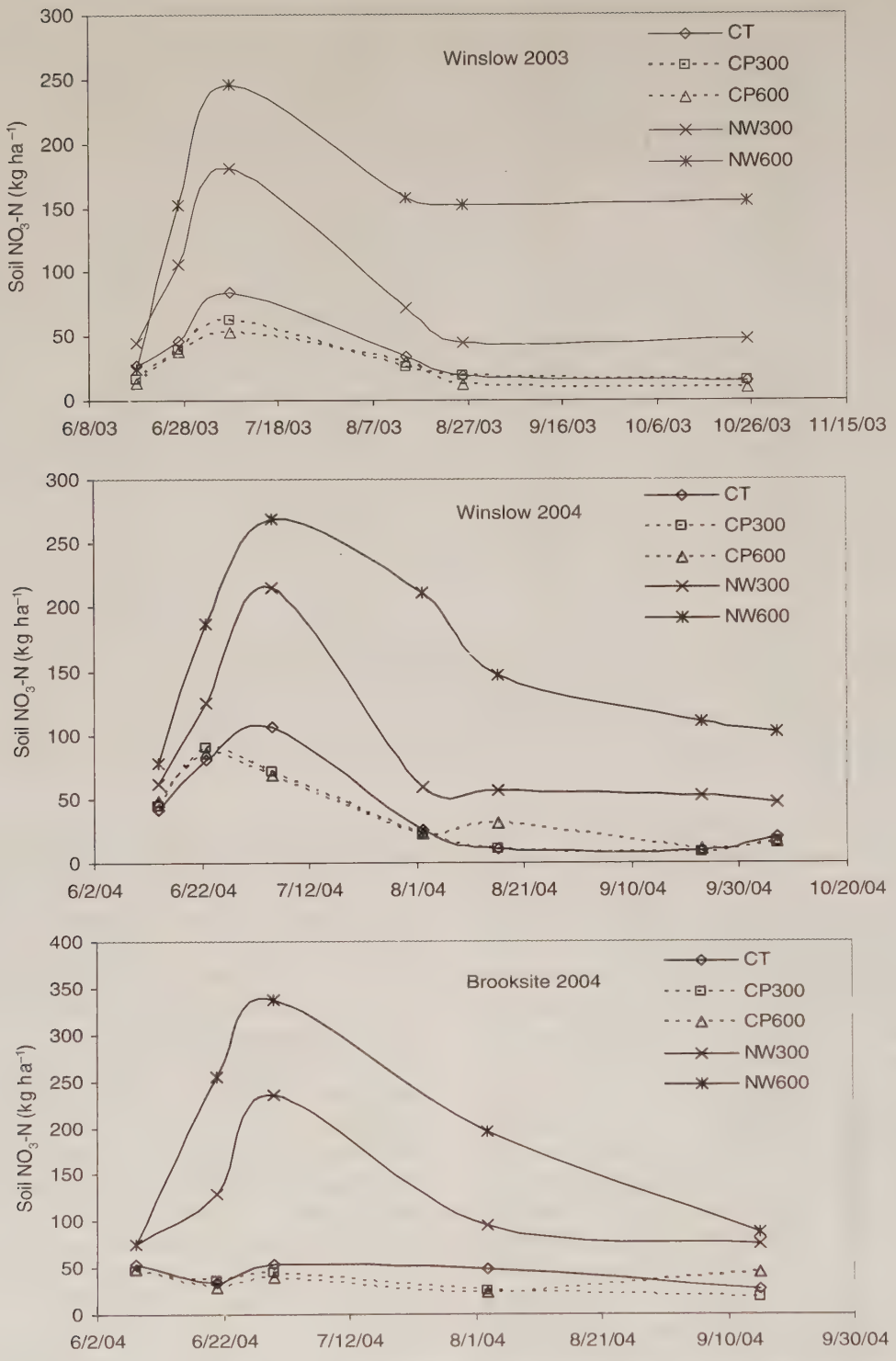


**Figure 1.** Seasonal changes in soil (0–30 cm) $NO_3^-$-N as affected by organic amendments over the three site-years (CT, un-amended control; CP300 and CP600, hog manure–sawdust compost applied, respectively, at 300 and 600 kg total N $ha^{-1}$; NW300 and NW600, pelletized poultry manure 'Nutriwave' applied, respectively, at 300 and 600 kg total N $ha^{-1}$).

can significantly improve yields, as shown when composts were applied in potato rotations[11,12,14]. In a study in Maine[13] the benefits of compost applied at 45 Mg $ha^{-1}$ fresh weight on root length density and tuber yields were attributed at least partially to improved soil aggregation. In the present study, compost significantly increased gravimetric soil moisture at 0–30 cm by up to 3% depending on sampling date (data not shown).

The PAN recorded for the Nutriwave treatments ranged from 33 to 39% (on average across all site-years), somewhat greater than our initial estimate of 30% for this product at pre-planting. An earlier study[35] obtained ANR

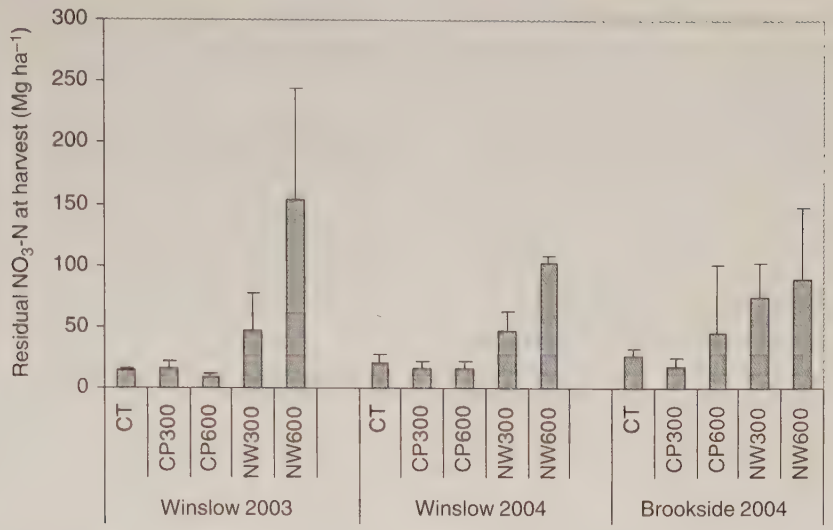


**Figure 2.** Soil (0–30 cm) residual $NO_3^-$-N at harvest as affected by organic amendments over the three site-years (CT, un-amended control; CP300 and CP600, hog manure–sawdust compost applied, respectively, at 300 and 600 kg total N ha$^{-1}$; NW300 and NW600, pelletized poultry manure 'Nutriwave' applied, respectively, at 300 and 600 kg total N ha$^{-1}$).

rates of 26–60% for a pelletized organo-mineral fertilizer product which combined poultry, dairy and hog manure and was of higher N content (7%). Assuming minimal in-season N losses, treatments NW300 and NW600 supplied an estimated 116 and 194 kg PAN ha$^{-1}$, respectively. As noted above, although small grains were the preceding crop, yield and tuber size responded to the lower of these N input rates alone. In a previous study, Shepody yield and tuber size were found to rarely respond to fertilizer N supplied at greater than 135 kg N ha$^{-1}$ when preceded by red clover[7]. An N credit in the order of 75 kg N ha$^{-1}$ was recommended where red clover was the preceding crop. These results at the Winslow site, given that a small grain was the preceding crop and that inorganic N levels recorded at planting were not unusually high, suggest that a relatively large mineralizable soil N pool accrues under the extended rotations practiced at this commercial organic farm. Supplementing a clover rotation crop with dairy manure compost at the much lower rate of 6.5 Mg ha$^{-1}$ (approx. 62 kg N ha$^{-1}$) was found in one study to significantly increase marketable yields of organic potatoes[9]. As the site had been previously managed organically for 4 years, the authors argue that even in post-transitional organic systems, organic amendments are likely required for high-N-demanding crops to supplement N supplied from leguminous green manures.

## *Seasonal change in soil nitrate*

There were treatment-by-measuring date interactions on soil $NO_3^-$-N at all three site-years, indicating distinctive seasonal changes in soil $NO_3^-$-N amongst the treatments. Soil $NO_3^-$-N contents increased at early growing season until hilling (30–35 DAP) and decreased thereafter. The seasonal fluctuation was more evident in the Nutriwave plots than in the other plots, especially at the Brookside site (Fig. 1). Soil $NO_3^-$-N remained considerably higher in the pelletized poultry manure plots than in the other plots throughout the growing season (Fig. 1). The effects of organic amendments on soil $NO_3^-$-N were also complicated by an interaction of source by source. The treatment NW600 presented a higher soil $NO_3^-$-N than the treatment NW300, while the difference was diminished between the two compost treatments. A gradual late season (August to September) decline in soil $NO_3^-$-N levels for the treatment NW600 was observed at Winslow and Brookside in 2004, but less so at Winslow in 2003 (Figs 1 and 2). This may be attributed to the later planting, topkilling and harvest date at Winslow in 2003 compared with 2004, combined with the slightly reduced rainfall (71 mm) received at this site during the month of September when compared with that received (82 and 81 mm) in September 2004 at Winslow and Brookside, respectively. A lower soil $NO_3^-$-N in the compost plots than in the un-amended control observed during most of the growing season either at the Winslow or at the Brookside site, once again, suggested net immobilization of soil N in the plots receiving high C/N compost. In un-amended plots, soil mineral N ($NO_3^-$-N + $NH_4^+$-N) levels to 30 cm depth at pre-planting ranged from 35 to 75 kg N ha$^{-1}$ (Table 1) in all three site-years, within the range reported regionally for potatoes at pre-planting following small grain cereals. In a survey of 228 conventionally managed potato fields in New Brunswick, Zebarth *et al.*[21] found that inorganic N levels to 30 cm ranged from 17 to 69 kg N ha$^{-1}$ where a cereal crop preceded potatoes, and 7 to 107 kg N ha$^{-1}$ with red clover or grassland as the preceding crop.

Soil residual $NO_3$-N to 30 cm depth after harvest was low for un-amended plots and compost plots (Fig. 2). Residual soil nitrate for these treatments, averaging less than 25 kg N ha$^{-1}$, was very low when compared with regional

averages of approximately 60 kg N ha$^{-1}$ soil nitrate at 0–30 cm depth following potatoes which received inorganic fertilizer[21]. Other studies also found residual soil nitrate to be low, in the range of 14–19 kg N ha$^{-1}$, for Shepody following barley or red clover but receiving no fertilizer N[26]. In contrast, the average residual soil nitrate for NW300 and NW600 was 61 and 141 kg N ha$^{-1}$, respectively, when averaged over all three site-years. While it would have been preferable to have data on residual $NO_3$-N to 60 cm depth, in previous Atlantic Canada studies, residual soil $NO_3$-N at 0–30 cm after fertilized potato harvest was highly related ($R^2 = 0.94$) to, and accounted for an average of 60%, of $NO_3$-N in the entire soil profile (0–90 cm)[10]. Very little leaching of nitrate to below the root zone appears to occur during the potato growing season, with most leaching losses occurring between seasons, although these losses can be highly variable between years[21]. Residual soil (0–90 cm) $NO_3$-N levels of up to 70 kg N ha$^{-1}$ were considered a 'reasonable level' achievable only when N fertilization is based on an economically optimum N application rate. Levels of inorganic N remaining in soil as high as 140–250 kg N ha$^{-1}$ derived from fertilizer N unharvested in the potato crop have been recorded in E. Canada, but with 50% of this residual N lost through nitrate leaching during the winter–early spring period[39].

## Conclusions

In an extended rotation characteristic of production practices on commercial organic potato farms in Atlantic Canada, relatively high tuber yields (~30 Mg ha$^{-1}$) were achieved without supplemental N application, in 2 of 3 years when seasonal moisture levels were non-limiting. Crop N uptake in un-amended soils averaged 112 kg N ha$^{-1}$. At the commercial farm site, significant reductions in marketable yield in the second year were due mainly to scab, attributable to high soil pH. In un-amended and compost-amended soils, residual nitrate N at harvest was low (< 25 kg N ha$^{-1}$) when compared with regional averages where inorganic fertilizer is applied. These results suggest that these systems are conservative with respect to N and minimize risks of overwinter soil nitrate losses. When soil moisture levels were adequate, application of a pelletized poultry manure product promoted gains in yields (+5.8 Mg ha$^{-1}$ average) when applied to supply an estimated 112 kg PAN ha$^{-1}$ (NW300), but residual soil nitrate levels rose to 61 kg N ha$^{-1}$. Similar benefits achieved in 1 of 3 years for compost applied at up to 48 mg DM ha$^{-1}$ (CP600) appeared due to 'non-nitrogen' benefits of compost. Yield effectiveness of NW decreased at higher rates of application (NW600). Most leaching losses of $NO_3^-$-N occur between seasons, and excessive levels of residual soil $NO_3^-$-N at harvest, as obtained for NW600 at 141 kg $NO_3^-$-N ha$^{-1}$, must be avoided. Given current premiums for certified organic potatoes, enhancing yields and marketable yields through application of amendments which supply moderate rates of N or organic matter appears warranted.

**Acknowledgements.** The project was financially supported by the Prince Edward Island Department of Agriculture and Forestry, the New Brunswick Department of Agriculture, Fisheries and Aquaculture, the Organic Agriculture Centre of Canada at NSAC, and the Canada Research Chairs program. Thanks are extended to F. Dollar, owner of Kentdale Farms, Winslow, PEI, for his participation in this study, and to K. MacNeil, A. Runnels, H. Purves, B. van de Pol, S. Urbaniek and A. Hammermeister for their excellent technical assistance.

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# Book Reviews

**Agrarian Dreams: The Paradox of Organic Farming in California.** By Julie Guthman. 2004. University of California Press, Berkeley, California, USA. 250 p. US$22.95, ISBN 0-520-24095-2, paperback.

In *Agrarian Dreams* Guthman gives us a fine-grained and historically rich analysis of how organic agriculture became big business in California. The question motivating the study is a critical one: how did organic agriculture become so similar to conventional agriculture in terms of industry structure, economic forces and political dynamics? Guthman addresses that question with a diverse approach, drawing on tools from social geography, land economics and interpretive sociology. Her multidimensional argument is summarized in several clear points. First, real organic farming in California is far from the small-farm agrarian ideal that seems to drive organic activism and consumption choices. Second, organic agriculture in California reflects a pre-existing landscape dominated by massive industrialized systems of production and marketing. Third, the contemporary organic certification system fails to promote the deeper social and ecological goals of organics, because they were made to institutionalize economic incentives for organic production. Finally, Guthman concludes, organic agriculture cannot lead to fundamental change in the food system until it is regulated by institutions that encompass the broader social and ecological goals.

After the introductory chapter, Guthman first explains the remarkable growth of organic production in California after 1980. In contrast to the first generation of growers, who were drawn to organic farming by 'deeply held political, environmental, philosophical, and/or spiritual values' (p. 23) most of the growers entering organics after 1980 were conventional producers seeking higher profits through new regulatory channels. Guthman shows this growth to be essentially 'demand-led', as intermediaries sought to satisfy the market mostly by recruiting the conventional growers they already worked with to convert part of their operations. 'Gentleman farmers', often orchardists, formed another key group drawn in by intermediaries. These commodity and specialty crop growers, facing new competition from the international market in the 1980s and 1990s, found organics to be a low-risk accessible way to seek higher value per acre. Products that were relatively easy to grow organically, such as processing tomatoes and wine grapes, increased in production the fastest.

Because the organic *movement* was eclipsed by the growing organic *sector*, the contemporary organic situation in California is structurally similar to agribusiness-as-usual, Guthman argues in the third chapter. While the median size of an organic farm in 1997 was 5 acres, over half of the organic sales accrued to the top 2% of growers (p. 43). Taking into account the vast number of hobbyist growers, the structure of organic agriculture in California is not really any different from the conventional sector. Guthman shows that farm ownership and land tenure are substantially the same, even when comparing all-organic growers with those who have both conventional and organic operations. She further rates growers according to agroecological principles and finds that very few (really only subscription farms) conform to ideals of high dependence on farm-based resources, biodiversity and permanent year-round workers. Similarly, most organic acreage is producing for conventional-style long-distance markets, another violation of the small-scale ideal. Given this situation, Guthman finds it unsurprising that most of the major growers express little or no commitment to the deeper political and social implications of organic agriculture.

In the fourth and fifth chapters, Guthman argues that the contemporary situation arises from how the organic boom grew on the pre-existing agro-industrial landscape. Her explanation focuses on how each successive wave of agricultural innovation creates higher expectations for agricultural value per acre, which then leads to higher land values. These higher land values then compel growers to seek maximum income from each piece, prompting innovation and further ratcheting up land prices. Chapter four describes how high-value crops such as vegetable and tree fruits replaced wheat early in the 20th century. The consolidation of packing and shipping locked in growers' reliance on low-paid contract labor in the 1930s and 1940s, instituting industrial relations in the system. Guthman argues that organics in the last part of the 20th century reproduced this dynamic, creating a new high-value stream linking contract labor, monocropping, and concentrated packing and marketing systems to distant retailers. These dynamics are shown in contemporary regional variation in organic farming – ranging from 'organic by neglect' to subscription farms pursuing social and ecological justice. Guthman describes and explains these regional patterns in chapter five.

Chapters six and seven focus on how the emergence of the current federally shaped certification system both reflects and reinforces the industrial character of most of the organic sector. The history Guthman gives in chapter six traces how the more complex social and ecological goals of organic agriculture became subsumed to industry concerns about instituting a price premium for organic production and creating a significant barrier to entry. As a result, organic standards came to focus on inputs rather than

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processes and land rather than people or operations. This price premium approach has serious consequences, Guthman argues in chapter seven. The overall effect was to narrow the range of auditable standards and limit their effectiveness in promoting long-term investments in ecological health and social outcomes. The materials list became a far-too-central arena for politicized debates about standards as well as a focus of manipulation. For example, Guthman describes a practice that violates the spirit, but not the letter of the rules: using a prohibited insect-attracting chemical just outside of a certified organic plot (p.152). Overall, the emerging standards led to an 'input-substitution' approach that fits in well with the labor, production and marketing practices of conventional agriculture.

Guthman comes full circle in the conclusion, warning that the family farm ideal, so dominant in organic agriculture discourse, is not only untrue but also unhelpful in envisioning and seeking a truly transformed agriculture. Scale is not the problem. Farmer independence is not the problem. The problem is relationships of exploitation that become taken for granted and reproduced in emerging agricultural systems. The populist agrarian vision does not, for example, raise the question of why farmworkers were not included in discussions leading to organic standards. It also does not address how the commodification of land or income inequality in American society limits the ability of organic agriculture to pursue social goals. In the final chapter, Guthman offers a few ideas for bringing the social and environmental aspects of organics into the foreground.

Guthman's argument is both provocative and persuasive, going beyond the hand-wringing that recent debates over organic regulation have prompted to offer an explanation of how and why actual existing conditions in California fail to realize the goals of the organic movement. The precise and straightforward writing style makes the key points all the more vivid. This book will likely find a home on the well-trafficked bookshelves of many activists and scholars.

My only disappointment with the book is that it does not address the counterfactual question: could it have been otherwise? By her account, it seems that standards were always about protecting a marketing category and were always driven by larger-scale market-oriented growers. Doesn't the massive growth of organics have to articulate with the pre-existing agricultural landscape? Her analysis raises a question: has organics 'conventionalized' or was it always, in a sense, 'conventional'? Was there a time when the organic label had integrity or did the very process of labeling take 'organic' from a way of life to a marketing category? This question was not Guthman's agenda, so my critique is perhaps misplaced. But nevertheless because this question is not addressed, the shape of the analysis tends to treat the conventional–alternative divide as more solid than it is. Despite my quibble, Guthman's ambitious and rigorous research adds an important empirical touchstone to an often unhelpfully abstract debate. This kind of situated analysis will help all of us understand different perspectives as well as the common values that will lead to tangible, positive change.

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doi:10.1017/S1742170508002342

**Agricultural Systems: Agroecology and Rural Innovations for Development.** Edited by Sieglinde Snapp and Barry Pound. 2008. Elsevier, Amsterdam, The Netherlands. 386 p. US$74.95, ISBN 978-0-12-372517-2, hardcover.

To welcome yet another book on sustainable development, a reviewer must look for what is unique and what adds value to the volumes already published. In *Agricultural Systems*, editors Sieglinde Snapp and Barry Pound have assembled a collection of chapters that goes beyond the usual praise and criticism of the green revolution and the focus on economic development. Their book provides a first-hand story by people with lengthy experiences in the field, especially in Africa, who have developed and tested grassroots, participatory development approaches. The result is a valuable set of principles, strategies and case studies that paint a new and feasible greenprint for development.

The first section on re-inventing farming systems describes agriculture as the heart of most developing country economies, but also a sector increasingly challenged by globalization, local poverty and pandemics such as AIDS. Improving systems will increasingly depend on innovative approaches, such as agroecology, that take into account the economic, policy and social issues in addition to the conventional focus on improving productivity. Ecological principles that relate to design of farming systems are becoming more important as we examine the complexity of rural challenges and the vital need to make best possible use of natural resources.

In a section on resources for development, four chapters delve into low-input technologies, nutrient management, decentralized plant breeding strategies and the role of livestock. Systems dependent on internal, renewable resources are more sustainable than those that require continued inputs from outside, inputs that have a high and increasing cost. Nutrient use is especially important, as we design efficient methods of cycling key elements within the farm and build toward the greatest possible complementarity among enterprises. Livestock in a mixed farming system can promote this nutrient cycling. Participatory plant breeding that is based on local germplasm and creative testing of new varieties by farmers under their own conditions can lead to better specific adaptation and secure seed supply.

Building a broader context for sustainable development is the focus of the concluding section, and includes an articulate discussion of why we should recognize and foster women's roles in development. Major sources of

innovation in the future will come from creative farmers, as well as from partnerships of researchers with farmers as equal partners in the development process. A final chapter urges adoption of a 'Green Evolution' strategy that emphasizes teams and collaboration, local solutions by local people, and engagement of stakeholders at all levels.

*Agricultural Systems* is particularly valuable in its practical approach to development and its focus on the role of farmers, especially women, in the process. Each chapter is supported by several case studies that direct the reader's attention to grassroots strategies that work. The chapter on animal systems is a welcome addition, since many similar books focus almost entirely on cropping systems. As with most edited volumes, there is patchiness in treatment and quality, and at times a lack of continuity, demonstrating the challenges of putting together a coherent story when the chapters are from many different people. Yet this is a useful book, with contributions from specialists who have spent decades in the development arena. It is well written and well worth adding to your personal library and recommending as a resource for students interested in developing countries and their agriculture.

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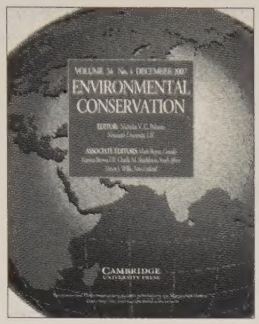


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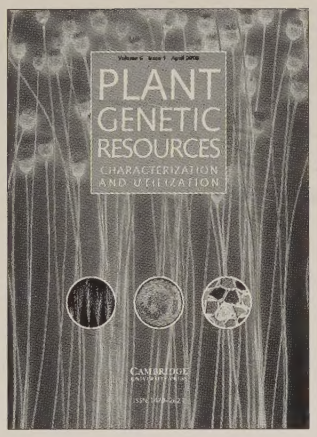


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Examples:

1. Leopold, A. 1991. The farmer as a conservationist. In S.L. Flader and J.B. Callicott (eds). The River of the Mother of God and Other Essays by Aldo Leopold. University of Wisconsin Press, Madison, WI. p. 255–265.
2. Brink, R.H. Jr, Dubach, P., and Lynch, D.I., 1960. Measurement of carbohydrates in soil hydrolyzates with anthrone. Soil Science 89:157–166.
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4. Arshad, M.A., and Coen, G.M., 1992. Characterization of soil quality: Physical and chemical criteria. American Journal of Alternative Agriculture 7:25–31.
5. Coale, F.J. 1996. Descriptions of the soil test interpretive categories used by the University of Maryland Soil Testing Laboratory. SFM-3. University of Maryland, College Park.

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